ALLIS-CHALMERS

ELECTRICAL REVIEW

S. R. Durand

March • 1940

Inspecting the leads of a 25,000 kw, 80 percent power factor, hydrogen-cooled generator stator.

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ALLIS-CHALMERS

ELECTRICAL REVIEW

C O N T E N T S


ACME

AN ENGINEER LOOKS AT WORLD WAR II

*Charles Sturtzen**

RECTIFIER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

Scuttled ships . . . smashing air raids . . . economic blockades . . . you've read about them every day. But here's the inside story of what's happening to European engineering and manufacturing companies behind the Siegfried and Maginot Lines.

For nearly two years prior to World War II, I had the experience of working in a European engineering office. The plant was located in the industrial center of Switzerland and thus about in the heart of Europe. Since Switzerland is a neutral country that still enjoys a democratic government in the fullest sense of the word, freedom of speech and press are taken for granted, and news from the outside world enters uncensored.

Switzerland, with its small area (less than half that of the State of Wisconsin) and its limited natural resources, has to import practically all raw materials that are needed in industrial processes. Consequently export is imperative in order to maintain economic equilibrium. This economic interdependence makes neutrality of vital importance. The people have realized that and have made it the fixed policy of the government to refrain from taking sides in the disputes that keep many other European states perpetually embroiled.

Neutrality

The individual European, however, is anything but indifferent to world politics. He hears and reads political news, forms his opinions or accepts those of others. Politically the Europeans are much more ardent than the people of this country. While baseball or football games occupy the minds of Americans a great deal and provide topics for conversation, the Europeans have never learned to enjoy these pastimes. Perhaps if they could learn to be less solemn and one-sided, the number of European wars would be cut down. As it is, their predominant theme of conversation is politics. Even if they settle down to a peaceful game of cards, they usually wind up with some heated political argument.

The Swiss are especially likely to do that. In spite of their government's rigid neutrality, the individual takes sides and has very strong political convictions ranging outside the boundaries of his own country. But in the life of industry, political views recede far into the background. I may say, this holds for all European countries and to a great extent even those in which the government exerts its controlling influence over speech and even thought.

In our plant worked people of almost every nationality. Their private views on politics were often antagonistic, but this did not affect their cooperative relation in office or shop. Much more startling was this behavior when business representatives from foreign nations — Germany, France, England, or some other—would visit to sell their goods. While the cleavage between the democratic governments and those of the totalitarian states became steadily greater, the men of industry would still meet each other on a common ground. It might be taken for granted that they would exercise mere tactfulness as business people. But more than that, these men found pleasure in their mutual acquaintanceship and displayed genuine friendliness.

Reactions of propaganda

Those people of a neighboring country, the far-reaching control of whose government even directed the policy of engineering publications, felt not always at ease when political advertisement and propaganda became too apparent in their technical magazines, which were often used during our discussions. I recall one incident when the works of Heinrich Hertz were mentioned.

Hertz was a great physicist. Setting out to prove experimentally the electro-dynamic field theory of

* Charles Sturtzen is an American engineer, who was employed in Switzerland for nearly two years immediately preceding the present conflict. The views expressed herein are opinions of Mr. Sturtzen and are not to be construed as representing the editorial policy of Allis-Chalmers ELECTRICAL REVIEW.

Maxwell, he was the first to succeed in doing so. It was he who discovered the existence of high frequency waves and demonstrated the relation between light and electricity. The term "Hertzian waves" has become a common technical expression. His nation was proud of him. His countrymen placed his bust in the hall of fame of the great industrial museum in Munich. Since that day politics has removed his bust from its niche, and his country's leading engineering magazine has now discovered that, though he died at the age of thirty-seven, toward the end of his life he had lost some of his former keenness of intellect. His work on the principles of mechanics was criticized, and its weak points attributed to the man's part-Jewish ancestry.

In such cases any thinking engineer would frankly admit that this sort of propaganda is not acceptable in the professional world. Perhaps it lies in the nature of engineers to be more conservative than some other groups and not to be easily swept away by the dictates of new political systems. From the human relationships of the profession which I saw in Europe one could never have predicted the looming catastrophe of war. It seemed always a great paradox to me how these people of different countries could meet as individuals to be friendly participators in a business deal, while in a political body they would try to exterminate each other.

Material problems

As the tension between the nations grew, the difficulties in our work increased. As always, the selection of proper materials from which the engineer builds his machines required careful study. Some materials improve; others are gradually changed by manufacturers and become often less applicable. Entirely new building products appear on the market. Their nature varies, and likewise their cost. Prices and qualities must be almost continuously checked and compared. This is one of the designing engineer's duties whether he works in America or Europe. But while the United States in its own country possesses a vastly greater variety of raw materials than any other nation, the selection in the European countries is narrowed down considerably. In addition to this limitation come the trade barriers as a result of import duties and quotas.

Business with France on the whole was very agreeable if one had patience to wait for delivery. France seems to be a nation that does not like to go along at 20th century speed. In my line of work, where flawless steel and high grade porcelain were required, we got better quality guarantees from Germany. But in doing business with German firms other difficulties arose. Their armament and war preparations were reflected more and more in the difficulty of obtaining materials that might be needed at home for these purposes. Germany was no longer interested in exporting steel for manufacture. The price quotations on steel, as we used it for anode plates of rectifiers, were so high that it could not be bought. Our own steel mills in Switzerland would often offer the same items at half the price of German quotations although the ore had first been imported from some other country. However, steel plate nine feet in width was too big for the Swiss steel mills and had to be imported.

Czechoslovakia proved to be a favorable supplier. But no sooner were business negotiations with Czechoslovakian firms well under way than Germany took over that country, and its businesses became coordinated with the rest of Germany and subject to the same restrictions. We had already had the same experience with Austrian firms. Much more severe for us than the changes in sources of supply were of course the lost markets, because the countries which fell into the German Reich were obliged to give business preference to the latter.

The Germans were, however, always very eager to sell products that required a great deal of their services. Service was what they wanted to sell rather than materials. In the case of porcelain insulators, for example — whose ingredients, such as kaolin, quartz, and feldspar, Germany has in abundance — the price quotations were low. But not steel.

In America we do not realize what a tremendous advantage results from the enormous variety and easy accessibility of raw and semi-finished materials. These things are taken for granted here and account for some of the wastefulness that is going on all the time. How different from American construction the technical designs in European engineering are can be understood when one realizes that while the ratio of labor cost to that of material is, for example, 25 percent for one particular machine in Switzerland, it is about 67 percent for the same machine made in America. In addition to the world problem of unemployment, the difficulties in obtaining materials were heightened by the lack of cooperation among the various governments.

Mobilization

And then came the war. With one big stroke was smashed what had been so laboriously worked out through months and even years. The whole machinery for useful production slowed down. Deliveries were delayed, and many of them stopped entirely. Those manufacturers with enough foresight had tried to fill their storerooms. I dare say few could do it since their economy did not permit hoarding. Business faced the most difficult problems. Although many orders were cancelled, work increased suddenly. New sources of supply had to be found. Many a design underwent a transformaton.

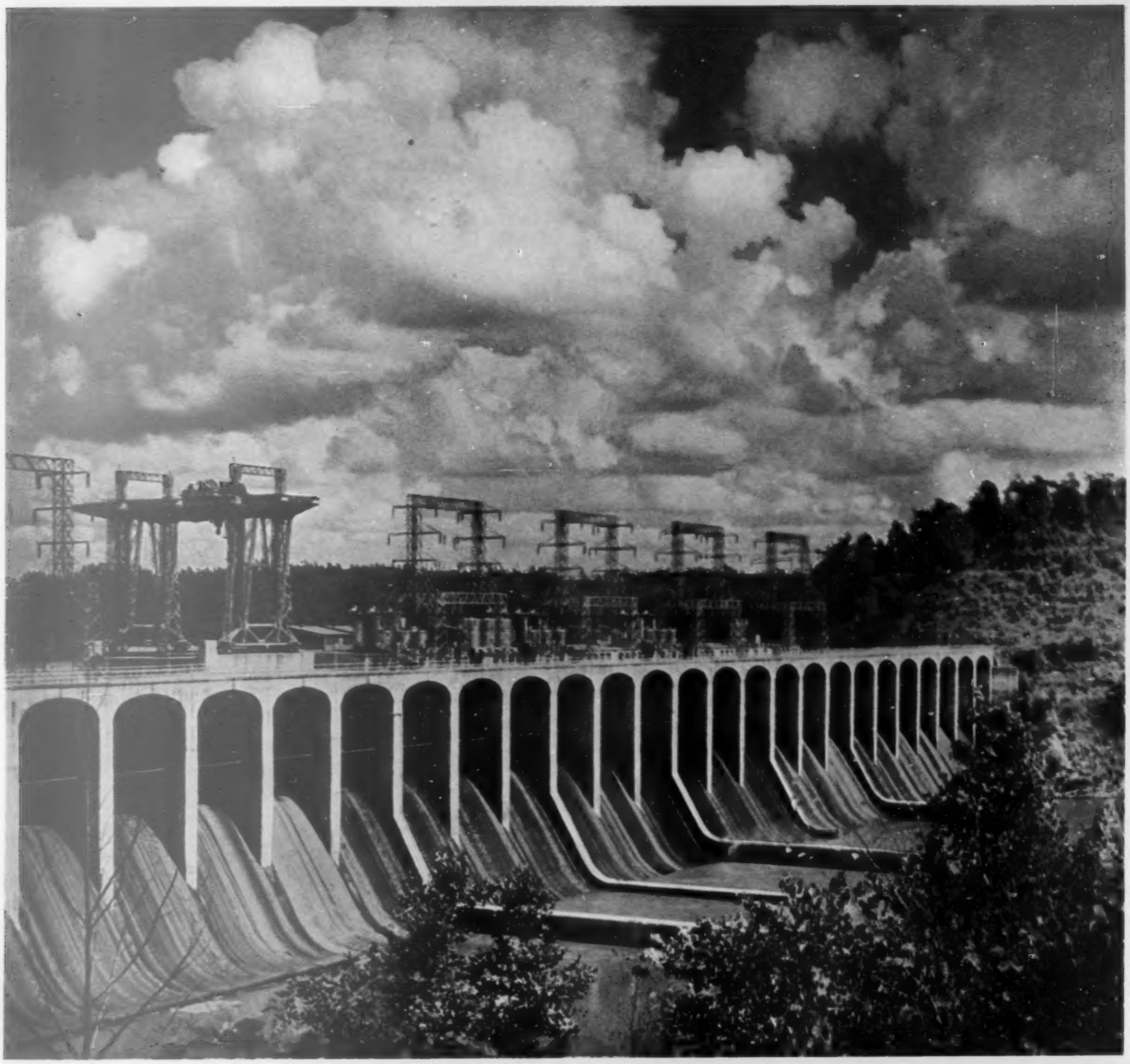
And yet this was not the hardest blow. The governments, whether at war or neutral, called their men into the army. It was a sad day for Switzerland as well as for other countries when the best of its male population exchanged their working clothes for uni-

forms. Day after day, endless trains of soldiers moved into their new posts. Schools were closed, and many of them changed into barracks or emergency hospitals. Nobody knew how soon these would be filled with victims of war. Public buildings, such as auditoriums, congress halls, and railroad waiting rooms, were spread with straw and converted into army quarters. A few days after mobilization the streets looked deserted except for women, old men, and children. Many stores were closed; others almost without male help. Women took over the work in postoffices, butcher shops, milk routes.

And in the factories and offices the staffs had shrunk to below 50 percent. Even men who had been in key positions were now somewhere at the border stringing up barbed wire. The few left at their civilian jobs had to carry on alone as well as they could. One can hardly visualize what a tremendous task of reorganizing went on during the weeks following the general mobilization.

Life did not stand still. It adjusted itself to the new conditions. Sad to say, many a milling machine and lathe is no longer used in service to mankind but for the production of machine guns and projectiles. History had previously seen plowshares melted into guns. We can only hope that this war will not last long enough to cripple the nations involved with its slaughter. Whatever the outcome, the scientists and technicians will again set to work, as they have before, to repair the destruction and to carry on the interrupted task of helping to build our civilization.

Contrast this peaceful scene below of a hydro-electric development on an Alabama river (Mitchell Dam) with the picture of war-torn Europe shown on page 4.



TO BEAT THE BAND

W. F. King

ELECTRICAL DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

That's the speed at which a modern motor travels. And a failure that shuts down an entire production line or endangers workmen . . . may be the fault of a 0.005 inch layer of mica . . . one of the many little things that go to make up correct banding.

● If an expensive, high-speed motor should fail, possibly causing a costly plant shutdown or endangering the operators, incorrect banding may be at fault. Hence, the importance of following the proper procedure in applying the band cannot be over-emphasized.

The purpose of this article it to describe a preferred procedure for banding the armatures of d-c machines and the rotors of slip ring type motors.

Band wire

The band wire as specified for d-c armatures and wound rotor induction motors is designed to resist the centrifugal force of the coil ends and insulation, allowing a conservative factor of safety. The band wire must be applied with an initial tension in excess of that caused by the maximum speed of the machine in order to prevent any movement or chafing of the coils.

Three grades of band wire are used:

1. Steel having a tensile strength of 210,000 lb per sq in.
2. Austenitic, non-magnetic steel with a tensile strength of 210,000 lb per sq in.
3. Phosphor bronze having a tensile strength of 120,000 lb per sq in.

The wire is tinned to facilitate soldering and must possess such toughness as to be bent through 180° flat upon itself without cracking.

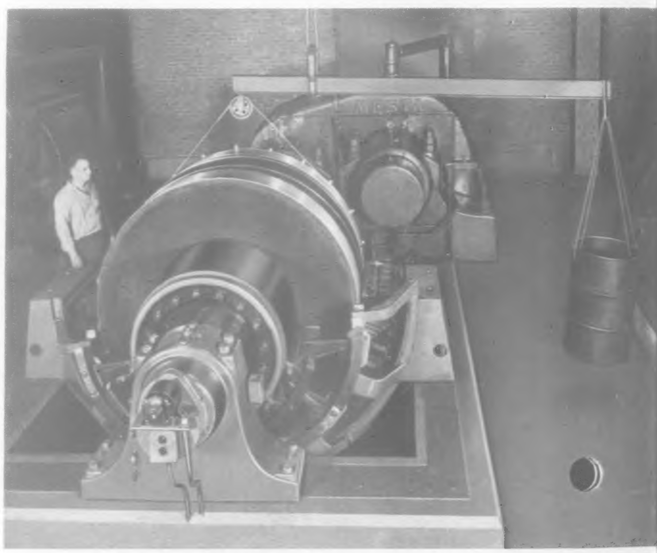
Non-magnetic steel band wire is used on wound rotor induction motors and on d-c armatures having a peripheral speed of over 5000 feet per minute. Plain steel band wire is used on armatures having a peripheral speed of less than 5000 feet per minute. The use of phosphor bronze wire has been largely discontinued in favor of non-magnetic steel, which, while more expensive, has far superior mechanical qualities. Non-magnetic steel band wire is not available on the market and must be obtained from the manufacturer of the electrical machinery.

Band insulation and clips

The band insulation consists of one layer half-lapped eight ounce (0.025 inch) varnished ducking and 0.013 inch fish paper cut in pieces six inches long and one-half inch wider than the band and applied together with the fish paper next to the band. In the case of class "B" insulation, one layer of half-lapped 0.005 inch mica folium is applied next to the coils in addition to the above.

The band wire clips are made of 1/32 inch by one inch wide tinned copper or tinned steel and are spaced eight to 12 inches apart, using the following rule:

Banding the armature of a 2500 hp d-c motor for steel mill service.



The number of clips must be an odd number that is not a multiple of any common divisor of the number of poles on the machine or closer than 10 percent (more or less) of the number of poles. For example, on a six-pole machine the number of clips used could be 7, 11, 13, 17, etc. Three clips are placed at the ends of the wire about three inches apart (Fig. 1).

The insulation and the clips are held in place with a few turns of cotton tape before starting the band.

When it is desired to subdivide the band to prevent eddy currents, a piece of flexible mica 0.020 inch by two inches wide is placed under three or four turns and then folded up to separate the turns at the designated place for the complete circumference, as shown by Fig. 2. The projecting part is trimmed after the band is completed. When the band is subdivided, it is also necessary to insulate the clips from the band with 0.005 inch mica folium cut one-half inch wider than the clip and as long as the band is wide.

The bands should have a slight dip at the center of the section to prevent them from moving end-ways. In order to form the dip it is necessary at times to wrap the coils with varnish-treated cotton tape under the band wire insulation.

If the coil ends of slip ring type induction motors show a tendency to twist or bend when being banded, spacers of insulating material should be inserted between the coil end clips in sufficient number to form a rigid arch of the coil ends and spacers when the band is tightened. (See Fig. 3.) The use of these spacers prevents the coil ends from turning over and allowing the band to slip off.

Baking coils

The best results are obtained by heating the coils before banding to make the insulation more flexible so as to allow the coils to be pressed into place more

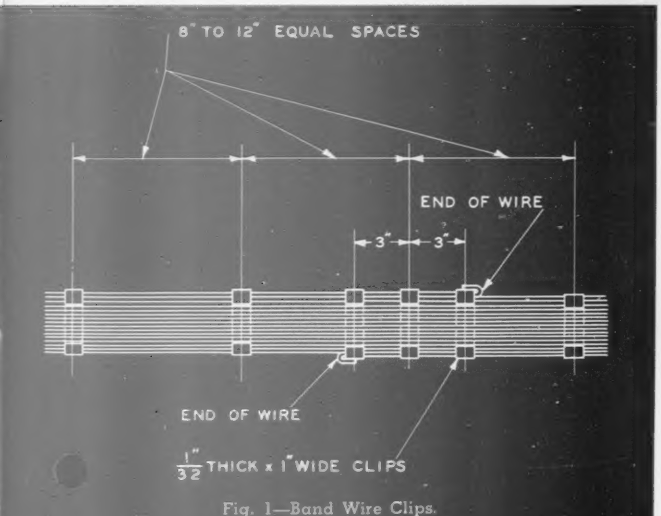


Fig. 1—Band Wire Clips.

easily and uniformly. The armature or rotor is heated either in an oven or by internal circulating current until a uniform temperature of 200 F is obtained throughout. The band is then applied while the coils are hot.

Temporary banding

Temporary banding, in general, is unnecessary when the permanent band is applied as described later in this article. However, in cases where the coils must be pressed to an unusual extent, a temporary band may be required. The coils are protected by using 0.040 inch fuller board under the band. At the end of the temporary band, the wire is anchored and the armature is allowed to cool to room temperature. Then the temporary band is removed, and the insulation and final band are applied.

When it is necessary to press the coils down in their slots, hardwood strips should be placed over the coils in the slots and a band wound over these strips with a helical pitch of two to three inches.

Banding procedure

The starting end of the band is anchored by attaching a cord, which has been wound around the armature, to a hook bent in the end of the wire and by crossing the second turn a number of times over the first. In addition the first two turns may be soldered together. Three or four extra turns are added at each end of the regular band (see Fig. 2). Adjacent turns of the regular band should touch, but the extra turns are set off a half inch or more. Where the extra turns run off the band insulation, the coil ends should be protected by placing 0.040 inch fuller board under the band wire. Both ends of the armature may be banded in one continuous operation. The wire is run on the armature with just enough tension to hold it in place. At the end of the band, three turns are run over a two inch by four inch by about four inch long wood block laid on edge which can be removed to pick up slack in the wire. The final end of the wire is soldered to the adjacent turn and to a clip.

Tension control

It is of utmost importance that the correct degree of tension be uniformly applied to the band. The device as shown in Fig. 4 and described below should be used to obtain uniform and accurate wire tension. The component parts can be easily procured on location for any banding job. The device consists of a timber, pipe, or light I-beam, one end of which carries a standard steel drum, such as an oil barrel, and the other end a sheave of at least ten inches diameter.

The beam is suspended from a crane hook, chain hoist, or block and tackle at a point one-fifth of the span from the sheave end. A beam ten feet in length is commonly used with the point of suspension two feet from the sheave support and eight feet from the barrel support. Water is added to the barrel to obtain the required loading as shown in the table (Fig. 4).

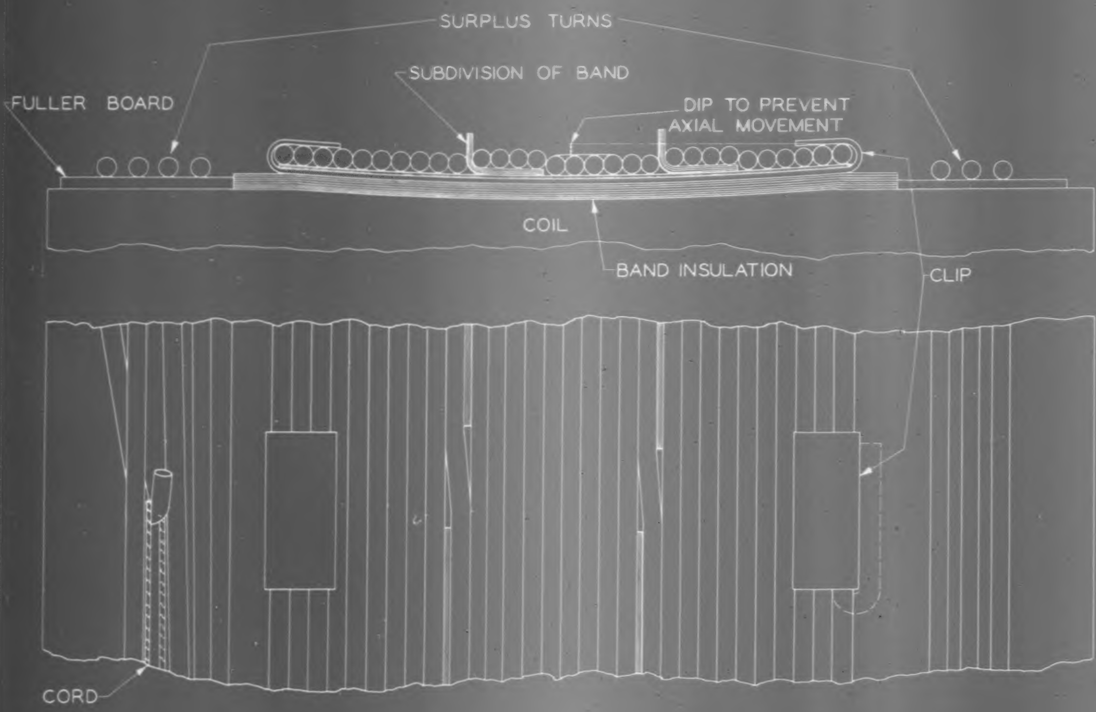


Fig. 2—Band Wire Section.

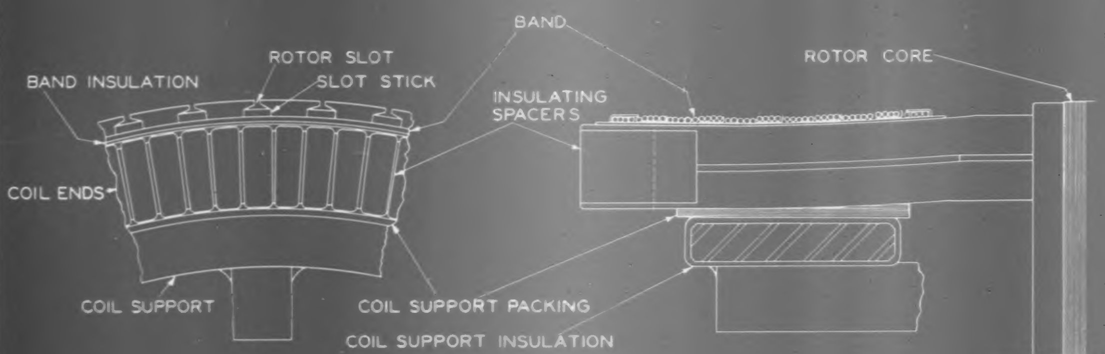


Fig. 3—View of the Coil Ends of a Slip Ring Type Induction Motor, Showing Spacers Between Coil Ends Under the Band.

The loading given in the table represents the total load required at the end of the beam, including the weight of the barrel and one-third of the weight of the beam.

After the band wire has been wound on the armature as stated above, the wood block is removed, and the slack thus provided is used to pass the wire over the sheave while the barrel is resting on the floor or on blocks. The tension device is lifted by means of the crane so that the beam is approximately horizontal with the barrel suspended free of other support. The included angle of the wire over the sheave is estimated and the loading adjusted accordingly. The armature is slowly turned to run the sheave across the width of the band and then reversed to run the sheave back to the starting point.

Slack removal

This process is repeated, raising the tension device as slack is removed from the wire so that the beam remains approximately horizontal. If the angle of the wire over the sheave changes appreciably, weight must be added to correct the loading. The sheave should not be run into the extra turns provided at either end of the regular band, as to do so may cause the temporary fastening of the wire to give way.

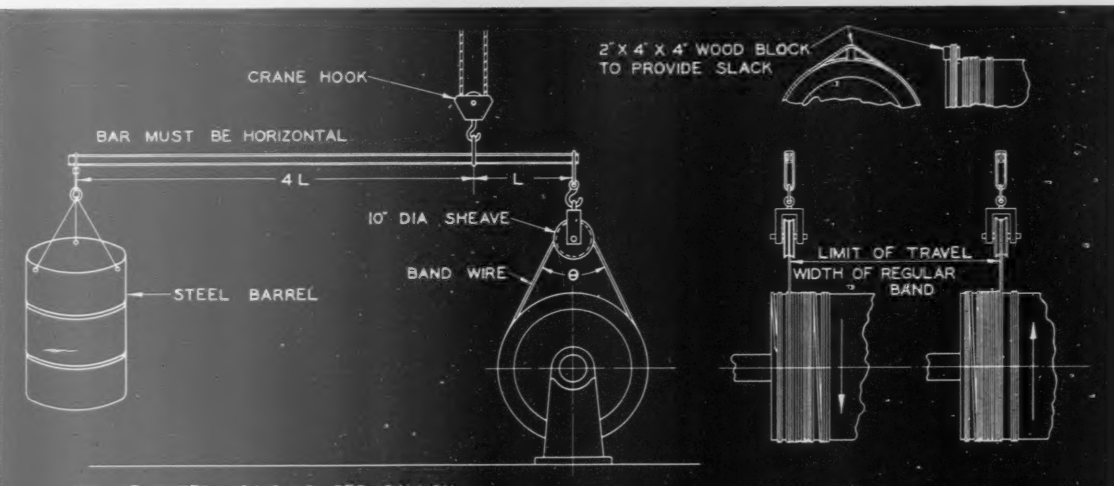
When no further slack can be taken up, the sheave is stopped just outside the regular band, and two clips are bent over and soldered at each end of the band. Then the tension is relieved, and the surplus turns of wire are cut off and removed. The ends of the wire are bent in the form of a hook over the third end clip, trimmed, and soldered in place.

The balance of the clips can then be crimped over the band and the entire band soldered. The clips are bent over about three turns of the band. All wires are sweated together and to the clips to make a homogeneous unit of the band.

The solder used should contain 50 percent or more tin. The melting point of solder ranges from 358 F for a mixture of 50 percent lead and 50 percent tin to 450 F for pure tin. When the soldering iron is in contact with the band wire, it should be kept in motion; for, if it is allowed to rest on the wire, annealing and consequent reduction in strength of the wire may take place. This is very important when phosphor bronze band wire is used. The maximum temperatures to which the various kinds of wire may be safely heated are:

Phosphor bronze	450 F
Plain steel	600 F
Non-magnetic steel	1000 F

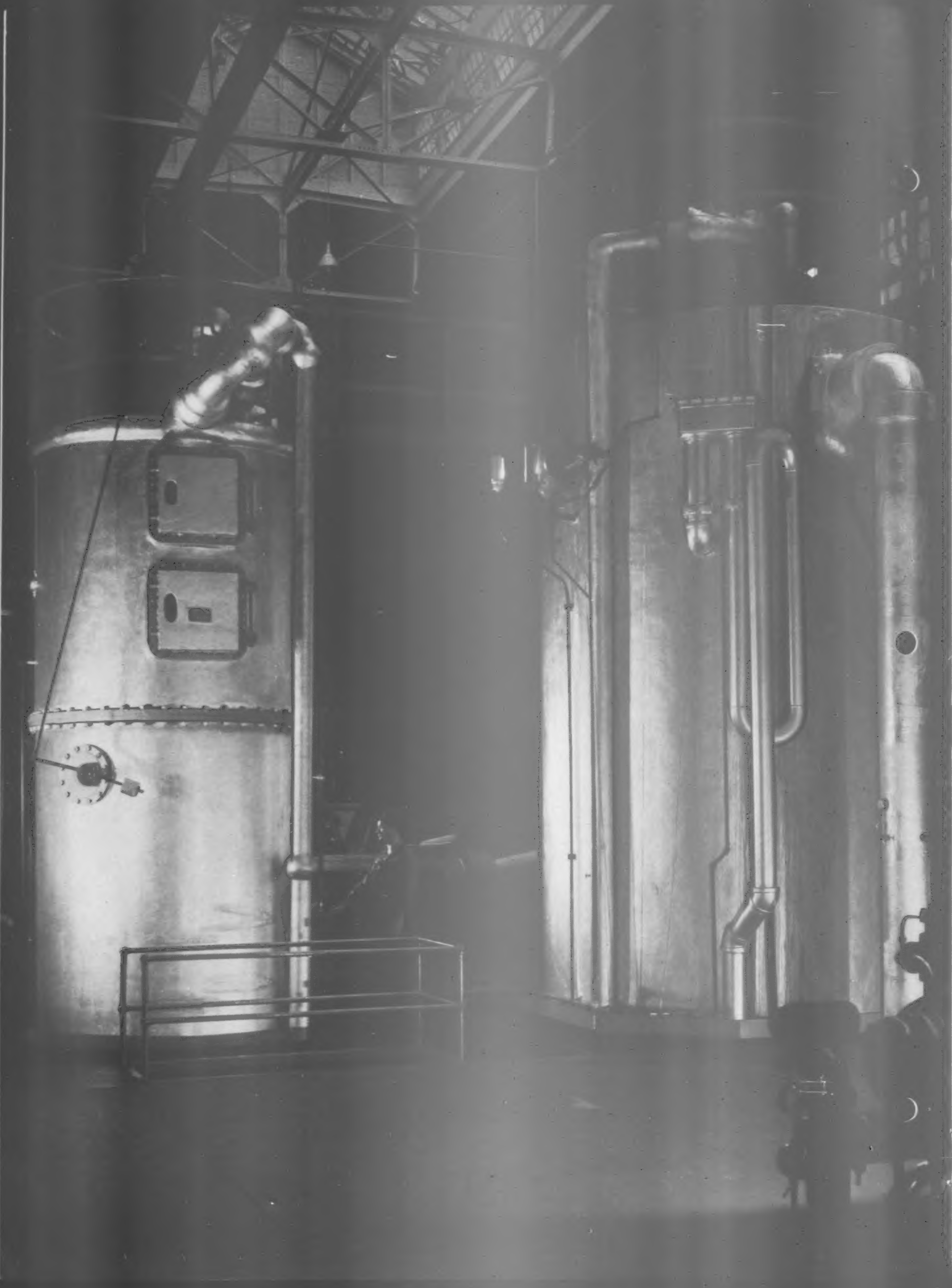
A soldering iron may be heated as high as 900 F without oxidizing the tinned surface of the iron.



TOTAL LOAD AT END OF BEAM INCLUDING WEIGHT OF BARREL AND 1/3 WEIGHT OF BEAM.

BAND WIRE			STEEL							PHOSPHOR BRONZE						
			TENSION IN WIRE		LOAD ON BEAM - LB					TENSION IN WIRE		LOAD ON BEAMS - LB				
					ANGLE θ OF WIRE OVER SHEAVE.							ANGLE θ OF WIRE OVER SHEAVE				
B.&S. GAGE	DIA IN.	AREA SQ IN.	FORCE LB	STRESS LB/SQ IN.	0°	30°	60°	90°	120°	FORCE LB	STRESS LB/SQ IN	0°	30°	60°	90°	120°
8	.1285	.01295	850	66000	425	410	368	300	212	600	46000	300	290	260	212	150
10	.1019	.00817	600	73500	300	290	260	212	150	400	49000	200	193	173	141	100
12	.0808	.00512	400	78000	200	193	173	141	100	250	49000	112	108	97	79	56
14	.0641	.00322	250	78000	125	121	108	88	63	160	50000	80	77	69	56	40
16	.0508	.00203	160	78000	80	77	69	57	40	100	50000	50	48	43	35	25

Fig. 4—Band Wire Tension Device.



WATER, WATER EVERYWHERE

S. E. Tray, Assistant Manager

FEEDWATER TREATING DEPARTMENT • ALLIS-CHALMERS MANUFACTURING COMPANY

And not a drop to drink . . . was the dilemma of the Ancient Mariner. But how to make water fit . . . not to drink . . . but to run boilers is the dilemma facing many power plants today.

"Better living through chemistry" is the keynote of one of the country's largest chemical manufacturers. This thought might well apply to the entire chemical industry, many of whose products lose their identity in the various processes which culminate in a consumer product. The romance of synthetic resins, synthetic silk, and other materials fabricated from the simple elements has captured popular fancy.

The World Fairs and industrial expositions of recent years have dramatized the story of the part that chemistry plays in our daily life. Somewhat less familiar is the role of chemistry in the chemical industry itself.

The field of chemistry embraces such a wide variety of subjects that no one organization can develop experts in all fields. The chemistry of water treating, for example, is a specialized field, including as it does physical chemistry, metallurgy, thermodynamics and metallography, interspersed with the ability to correlate this knowledge with the problem of generating millions of pounds of steam per hour efficiently and without interruption.

Most chemical processes are of a continuous nature and cannot suffer interruptions which might result from failure of boilers or steam turbines in the power plant. The mere fact that a chemical manufacturer usually has available a large number of chemists on his staff does not necessarily mean that they are capable of supervising the treatment of water. As a matter of fact, it is in chemical plants and in the allied industries, such as paper mills, oil refineries, packing plants and steel mills, that the limits of chemical knowledge in any particular field are most readily recognized. It is not surprising, therefore, that many of the country's largest chemical plants have called in competent consultants to assist them in the solution of their water-treating problems.

AT LEFT: Typical feedwater treating layout for a modern power house — deaerating heater (left) and water softener.

High make-up problem

One of the most interesting recent installations involves the operation of a 950 lb boiler together with a high pressure, back pressure turbine supplying steam and power for chemical processes. While the boiler operating pressure is not unusual in the light of present-day power developments, the installation is unique in that all of the steam, after passing through the turbine, is used for processing and heating; and, as a consequence, there is none available as returned condensate for boiler feed purposes. Thus, it is necessary for the boiler to operate entirely on make-up water with the exception of a small dilution from steam used in the feedwater heater.

The operation of a boiler at this pressure with such a high percentage of make-up has never before been attempted in this country; and, because of the definite trend in many industries toward high pressure, high make-up plants, this installation will be watched with considerable interest.

The treatment of the make-up water for this plant is complicated by a variable supply of river water containing, at certain periods, considerable sewage and organic matter as well as insoluble matter in colloidal suspension. While the treating requirements are made more severe because of the operating pressure and the high percentage of make-up, they are also critically affected by the design of the boiler.

The furnace is water cooled throughout, including the top as well as the floor, and because the boiler is gas-fired the heat transfer to the furnace tubes is appreciable. Because gas is used for firing, there will be no insulating slag accumulations on the outside of the tubes to assist in reducing the heat transfer through the furnace tubes. When it is further considered that this installation is comprised of only one

boiler and one turbine on which the entire plant production depends, the necessity for proper treatment of the boiler water can be readily understood.

In developing the water treatment for this installation, several problems of a local nature arose which had to be considered in the final design of the system. Incidentally, it is the presence of these individual problems which makes it necessary that each installation be considered as a separate study. It is impossible to formulate a standard design to meet all conditions.

Old plant

The new boiler and turbine were installed in a plant already built and in which low pressure boilers were operating. The water for the low pressure boilers was treated by means of an antiquated hot lime and soda softener in which the chemical control was somewhat irregular. Because of the low operating pressure of the old boilers and the low ratings at which they were operated, this system had not given any particular trouble. The original installation consisted of three separate settling tanks with a capacity of 25,000 gallons each. The three tanks operated in parallel, and the chemical proportioner was designed to feed chemicals simultaneously to each of the three tanks.

Figure 2 shows a schematic arrangement of the original system, on which it was difficult to obtain accurate chemical control because the separate chemical feed to each tank was actuated by the flow of water to all of the tanks. Under such an arrangement it was possible for water to be drawn from one tank more rapidly than the others, resulting in undertreatment with chemicals and an appreciable reduction in temperature that further reduced the effectiveness of the lime and soda treatment. Although the filters following the original settling tanks were of a non-siliceous material, they had been in service for some years during which their capacity had been affected by channeling.

A study of the raw water supply indicated that the water contained total solids to the extent of about 100 ppm (parts per million), chiefly bicarbonates. While the water was not subject to extreme variations in chemical constituents, it was contaminated from time to time with sewage and organic matter.

It was deemed advisable to utilize as much of the old water-treating plant as possible, not only to reduce the initial installation cost, but also because of the necessity of utilizing the available space to the best advantage. With this in mind, it was decided to continue with the hot lime and soda ash treatment as a primary step in the softening, but to modify the existing installation to permit the use of one of the alkaline phosphates as a secondary softening agent external to the boiler.

Preliminary tests on the water indicated that the conventional lime and soda treatment under the best conditions of control could produce an effluent with a hardness from 12 to 14 ppm. These tests further demonstrated that the lime-soda reactions would be practically complete within a period of ten minutes at a temperature of 210 F. This ten minute retention period, of course, did not include any time for settling of the sludge produced by the action of lime and soda ash, but it did insure that all of the softening which could be expected with this treatment would occur.

Sludge prevention

An effluent containing 12 to 14 ppm of hardness is generally considered a fair type of make-up water,

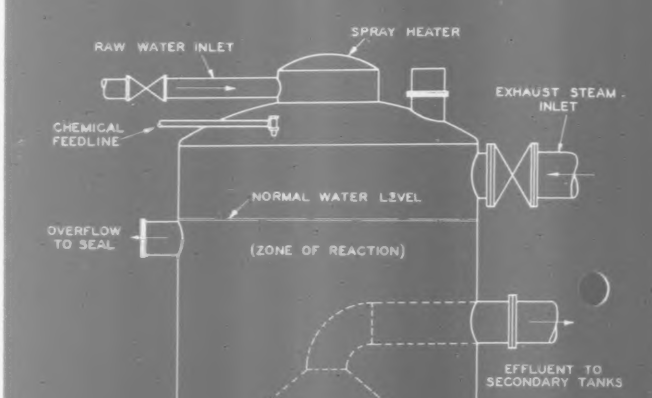


Fig. 1—Essentials of Primary Sedimentation Tank.

since the residual hardness in the effluent can usually be further precipitated by the addition of chemicals directly to the boiler. In this particular instance, however, the precipitation of this residual hardness in the boiler would result in the production of approximately 15 lb of sludge per 1,000,000 lb of water fed to the boiler. In view of the high percentage of make-up required for this plant, as well as the operating characteristics of the boiler, it was desirable to reduce the potential sludge-forming characteristics of the feedwater to a minimum before entering the boiler.

To accomplish this, a secondary treatment of phosphate was selected which would reduce the hardness to a value below 5 ppm and which would ultimately result in a 60 percent reduction of the potential sludge formed in the boiler. Laboratory tests confirmed the fact that the addition of phosphate to a water containing precipitates from lime and soda ash treatment would settle satisfactorily and, upon filtration, would give a clear effluent with a minimum of hardness and the absence of any soluble phosphate.

Since one of the difficulties with the original water-treating plant had been inaccurate control of the chemical treatment, a new design was developed in which the lime and soda ash was introduced at only one point in the system, in proportion to the flow of water required. This necessitated the installation of a primary settling tank ahead of the three sedimentation tanks which were already installed. One purpose

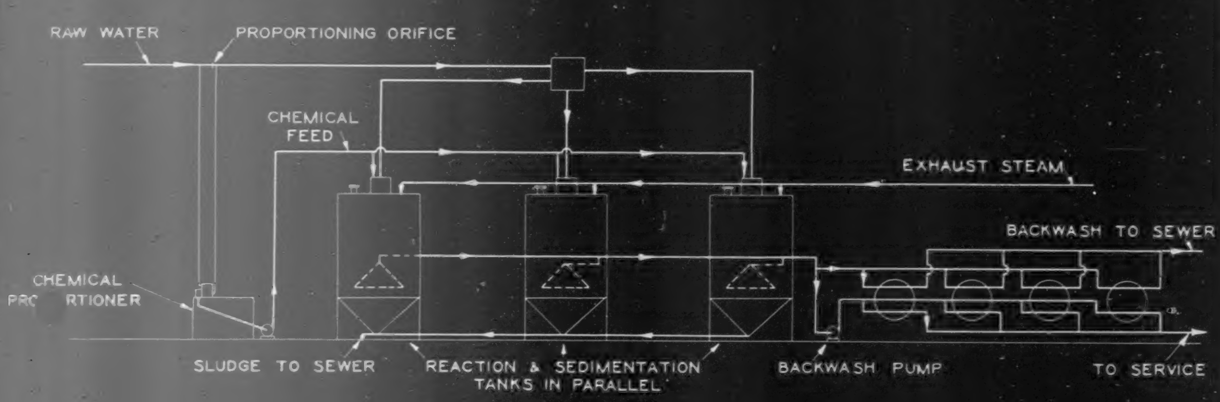


Fig. 2—Arrangement of Original Plant Before Alteration.

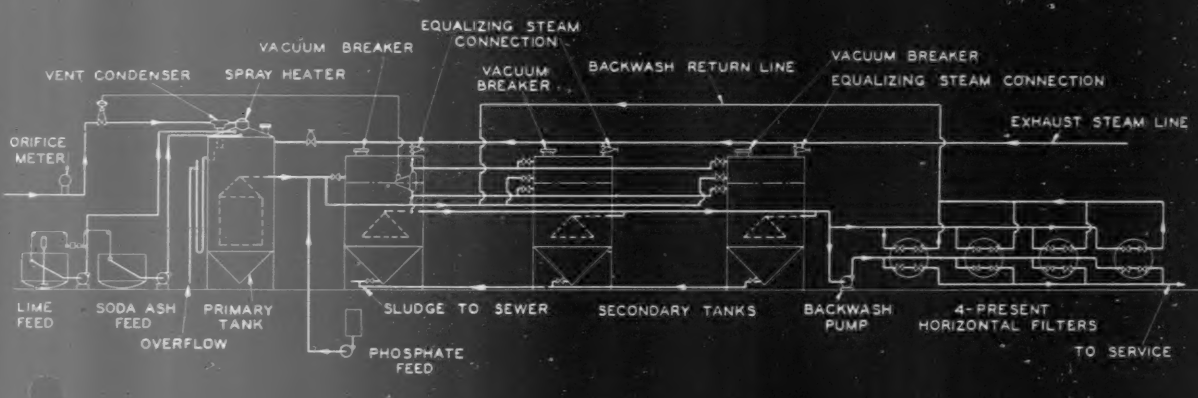


Fig. 3—Flow Diagram with Provision for Primary and Secondary Softening.

of the primary tank was to provide a central point for the addition of water and lime and soda ash under a single control. Because of space limitations, however, it was not possible to design a primary tank to have a capacity equal to the combined capacities of the three existing or secondary tanks. As it had been previously demonstrated that the lime and soda reactions were completed within a relatively short period, advantage was taken of this to design the primary tank for a retention period of only 15 minutes.

Primary tank

It was realized at the outset, however, that such a limited retention period would not provide for proper settling and sludge removal in the primary tank if the conventional settling tank were used. Accordingly, the design of the primary tank was developed to provide for the maximum length of travel downward and upward through the tank, without any increase in velocity of the water as the direction of the flow was changed. Fig. 1 shows the essentials of the primary tank design and indicates the method of obtaining the desired flow at constant velocity through the tank.

The amount of sludge to be handled in the primary tank and the limited retention period make it necessary to obtain the greatest possible removal of sludge. The reversal of flow and constant velocity in the primary tank achieves this condition by permitting an accumulation of sludge to exist in the form of a "sludge curtain" part way up in the inner cylinder. This "sludge curtain" occurs at the point where the effect of the upward velocity of the water is just balanced by the effect of gravity on the sludge particles. Thus the sludge itself is, in effect, used as a filter medium, and the sludge removed from the primary tank is considerably in excess of what would normally be possible.

The effluent from the primary tank will still contain an appreciable quantity of sludge, which then flows by gravity to the three existing settling tanks that now act as secondary softeners. One of the alkaline phosphates is introduced at the outlet of the primary settling tank and, with the residual lime and soda sludge as a nucleus, the finely divided calcium phosphate precipitates readily, settling in the secondary tank. Fig. 3 shows a schematic diagram of the treating plant as a unit.

The retention period in the secondary tanks is sufficiently long to insure practically complete sludge removal. The existing filters have been changed, and anthracite coal, properly graded, is now used as the filter medium. The control of the lime and soda ash treatment is regulated by a differential pressure orifice which actuates an electrical control device. The addition of phosphate following the primary softener is manually controlled. Because of the uniform load and constant quantity of the effluent from the primary tank, manual control has proven entirely satisfactory.

Reactions

The chemical reactions involved in the primary and secondary softening are given below in Fig. 4. It is interesting to note that proper control of the pH value in the secondary tank is necessary in order to provide for the complete precipitation of calcium phosphate. The influence of pH value on softening reactions is shown graphically in Fig. 5*. The minimum solubility of both calcium carbonate and calcium phosphate occurs at pH 9.0 and above. For calcium phosphate, the solubility approaches zero at pH 10.0; hence, in the secondary tanks the lime control must be such that the reactions take place in this range. This is essential if the presence of soluble phosphate in the softener effluent is to be avoided.

(Lime)	$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$
(Soda Ash)	$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$
(Phosphate)	$3CaCO_3 + 2Na_2HPO_4 = Ca_3(PO_4)_2 + 2Na_2CO_3 + H_2O + CO_2$

Fig. 4

After filtration, the water enters a deaerating heater in which a major portion of the dissolved oxygen is removed, and the water is then pumped directly to the boiler. The absence of stage heaters and economizers following the boiler feed pump eliminates the possibility of any increase in the feedwater temperature after leaving the deaerating heater. Therefore, in spite of a small residual hardness in the feedwater, no deposits will occur in the boiler feed pump or feed lines. The normal procedure is to follow an external phosphate treatment with acid to reduce the pH value of the water, thus preventing deposits at points of increased temperature. In this instance, however, acid was not required, and the treatment was considerably simplified.

In the boiler proper, a slight amount of phosphate is added directly by means of a high pressure chemical pump. This insures the precipitation of the residual hardness in the entering feedwater as calcium phosphate, but does not permit any excess soluble phosphate in the boiler water. The low pressure boilers receive the effluent from the new softener installation, but operate without further supplementary treatment.

* Function of pH in Water Treatment, C. E. Imhoff, Technical Ass'n. Pulp & Paper Institute, Feb., 1940.

Reduction of silica

The prevention of silica scale is one of the principal problems in high pressure boilers, particularly those operating with high make-up requirements. The silica content of the raw water averages about 4 ppm, and previous studies had indicated that this could not be economically reduced by any external treatment. Since the silica content is practically unchanged by the lime-soda-phosphate treatment, 20 concentrations in the boiler water could result in a silica content of 80 ppm in the boiler if it all remained soluble. The effect of highly soluble silica in boiler water on turbine blade deposits and in forming analcite scale deposits is well known†, and it was deemed advisable to reduce the soluble silica to a value of less than

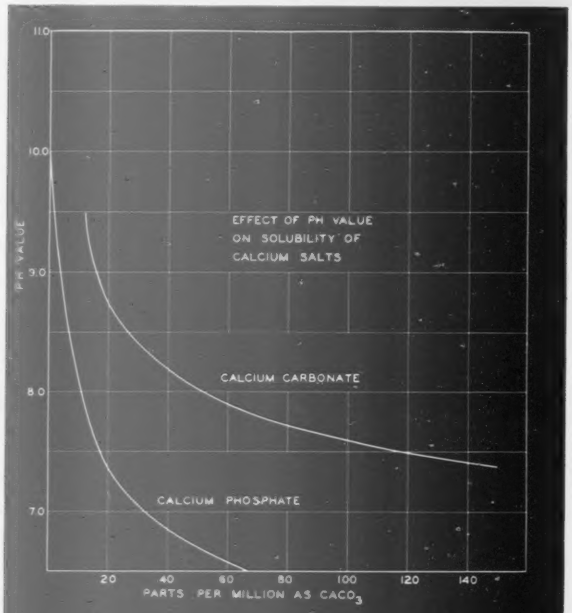


Fig. 5

two percent of the total solids. With total solids of 3000 ppm in the boiler water, experience indicated that the soluble silica should be maintained below 60 ppm.

To accomplish this, a dispersion of metallic iron in hydrous ferrous oxide is added to the feedwater at the feed pump suction. The insoluble ferrous iron in the boiler water then provides a medium for the absorption of soluble silica, which precipitates as a sludge along with calcium phosphate in the boiler. This is analogous to the external removal of silica with iron salts, which has received considerable attention in recent years‡, but is more effective because of the higher initial concentration of silica in the boiler water as compared to the raw water.

† Boiler Operation As It Affects Prime Movers, S. E. Tray, Mechanical Engineering, June, 1938.

‡ Removal of Silica from Water, M. C. Schwartz, Journal of American Water Works Ass'n., Vol. 30, p. 551.

Further advantages of iron

In addition to preventing silica deposits, the use of iron internally in the boiler changes the character of the calcium phosphate sludge. Normally this sludge is of a finely divided, adherent nature and tends to deposit on the heating surfaces of the boiler to such an extent that circulation is interrupted and tube burnouts occur. The presence of iron, however, renders this sludge more flocculent and, by increasing the particle size, helps to maintain the sludge in circulation so that it can be removed readily by the boiler blow down.

Another function of the internal addition of iron is to absorb the residual oxygen left after the feedwater heater, thus providing a second line of defense against corrosion in the boiler and turbine. As the addition of iron does not involve the introduction of any soluble salts to the boiler water, it is readily apparent that concentrations, alkalinities, and proper ratios between various salts are not affected in any way by its use.

The water treatment developed for this installation, consisting of a primary and secondary external treatment, followed by a supplementary internal treatment, represents the steps deemed necessary to condition properly a contaminated river water and make it suitable for use as boiler feed. The design of the treating system has fulfilled the first requisite of proper treatment — that of precipitating the major portion of the solids in the raw water outside the boiler. The other requisites of a correct boiler feed demand that the water shall

(1) be free from scale-forming salts
(2) be non-corrosive
(3) be non-embrittling
(4) be free from any tendency to carry over with the steam.

How well these requisites have been met can be determined only by close daily analyses and by the operating record of the plant in the future. Careful control of the various steps in the system by the operating personnel is absolutely essential if expected results are to be obtained. The development of the treatment and installation of the equipment is only the initial step in the work of the water consultant. His is the responsibility of anticipating trouble from changing conditions before it occurs. As is so often the case, eternal vigilance is the price of continuous operation, on which the chemical industry is so dependent.

ON FOLLOWING PAGES: Looking into the plate steel spiral casing of a 13,300 hp hydraulic turbine for Santee-Cooper Dam, 35 miles northwest of Charleston, South Carolina.

TIN CANS AND AMERICAN BEAUTIES

T. B. Montgomery

SWITCHGEAR DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

The common denominator between tin cans and the steel products of the automobile industry, aptly termed "American Beauties," is the sheet steel of which both are made. Eye appeal and health preservation are rolling out of our modern cold strip mills at one-third mile a minute, 24 hours a day.

● Eye appeal and health preservation are rolling out of our modern cold strip mills at one-third mile a minute, 24 hours a day!

Consider the years insurance companies add annually to the life expectancy of man — due in no small measure to the sanitation and vitamin-fresh food value sealed in the tin can.

Consider the admiring throngs surging about the new streamlined American Beauties at the auto shows — it all emanates from rapid development in the cold strip mills.

Vitally important in the chain of processes is the plant of the steel manufacturer, for these products are fabricated from steel strips hot rolled from slabs approximately 4½ in. thick down to approximately 0.1 in. to 0.06 in. and then cold rolled to finished gauges. Until approximately a decade ago, it was general practice to hot roll this material to finished gauges.

Primitive

To begin at the beginning, from the village blacksmith almost everyone is familiar with the method of elongating iron heated to redness by swaging under hammer blows, as in Fig. 1. If the hammer blows are directed in the line of the arrow, most of the elongation is lengthwise of the bar.

In a similar manner, if the steel in a mill is directed between rolls with sufficient pressure between them, the steel will be elongated uniformly. Something of a swaging action takes place. Steel of temperatures above approximately 2000 F so rolled is, in general, hot enough to be self-annealing in the elongated state after being rolled, so that when cold it is soft enough to work again.

Figure 2A shows the general arrangement of a three-high hot mill for steel sheets formerly in use. The operator on one side of the mill would insert the sheet between the rolls by means of tongs or other tools, and it would be caught and returned through the lower set of rolls by an operator on the opposite side.

Figure 2B shows a two-roll mill used for thinner gauge tin plate, in which the material was put through in packs, later to be separated by hand. If more than one operation was required, it was returned through another set of rolls.

At best, it was back-breaking work in torrid atmospheres. Furthermore, on the latter mill eight to nine tons of standard widths were considered normal production for eight hours from a mill crew. Such material could not be given highly finished surfaces, and quality was uneven.

Originally a line of such mills was driven through multiple rope drives acting on a common line shaft from steam engines, mostly of the Corliss type. Later engines and ropes gave way to a-c, or occasionally d-c, motors with the early simple types of equipment for starting them. No other control than this was needed, as operation was at constant speed.

Cold rolling

Steel can also be reduced by rolling in the cold state, but serious difficulties arise. In applying this method the tremendous roll pressures required exceeded the limits of strength of available roll material and therefore caused deflection or breakage of the rolls. The next natural step was, therefore, to develop the four-high mill, in which relatively large backup rolls (see mill rolls, Figs. 5, 6, and 7)* were used to prevent deflection of the work rolls operating on the strip. This type of mill increased the allowable roll pressure, but the results left much to be desired.

The reason was definite: while sufficient pressure was available to get greater reduction, steel when rolled cold "work hardens"; that is, the elastic limit becomes greater. For example, with no annealing effect present and with the maximum roll pressure available, 15 percent reduction was obtained in a

* Backup rolls—"a" Fig. 5; work rolls—"b"—Fig. 5.

single pass.* The percentage of reduction in each succeeding pass, however, became smaller because of the increasing hardness of the steel. Soon a point was reached where no further reduction was possible without an expensive annealing process.

However, steel may be reduced by another method. One has but to recall the laboratory for testing strengths of material. Fig. 3 shows two low carbon steel test bars or rods. Rod "A" is in the original state, while rod "B" has been subjected to a tension in the lengthwise direction greater than its elastic limit. As shown, rod "B" has been elongated approximately 9/16 inch, and its cross section reduced.

Figure 4 shows the relative elongation of such material per unit of tensional stress applied. When tension is applied, the rod elongates in proportion to the tension up to the point "A" (the elastic limit), and when tension is removed the rod returns to its original shape. Therefore, if a lengthwise stress up to approximately 36,000 lb per sq in. is put on the bar, the rod will elongate in proportion to the stress; but when the stress is removed, the rod will return to its original length and cross section.

Fig. 1

Fig. 2A—Three High Hot Mill (Old).

Fig. 2B—Hot Mill for Tin Plate (Old).

Greater values of tension, however, permanently elongate the rod and reduce its cross section. If the longitudinal stress is raised above 36,000 lb per sq in., the material will elongate more than proportionately to the unit stress, and its cross section will be reduced in proportion to the elongation. After the stress has been removed, the material will remain in the elongated state, and its cross section will have been effectively reduced.

This method of reducing produces a different grain or atomic structure from that produced by roll pressure only. Consequently the appearance of the tandem mill, Fig. 5, seems a natural step wherein a series of mills are so placed that the strip passes from one to the other in a series of steps or passes.

The tandem mill

The tandem mill added two desirable features over the old mills: first, passing the strip from one mill to the next consecutively eliminates the handling required in passing it back and forth as in Fig. 2A; second, it is possible to obtain tension between stands or mills with this arrangement.

Maximum allowable screw pressure is exerted on the four-high rolls when required, and mill speeds are adjusted so that tension is held between mills or stands. The tension reduces the roll pressure required for a given reduction. Thus greater reduction is effected by a combination of tension and roll pressure. It is desirable to carry tensions between stands roughly equivalent to the unit values at point "B," Fig. 4. This point is selected because if the tension goes even momentarily above 71 000 lb per sq in., the strip will be pulled apart; while if it falls below 36,000 lb per sq in., no permanent elongation due to tension will take place. In Fig. 4 the actual unit stress is the pressure in pounds per square inch based on the reduced cross section after stress is applied. The apparent unit stress is the pressure in pounds per square inch based on the cross section before stress is applied.

Basically this process makes possible present-day quality of steel because the addition of tension, together with careful steel analysis, has made possible a grain structure suitable for deep drawing in large dies common at present; while roll pressure from

* Each time steel is reduced by being passed through rolls, such a process is termed a "pass." Successive passes may be in different mills in series or tandem, or in the same mill.

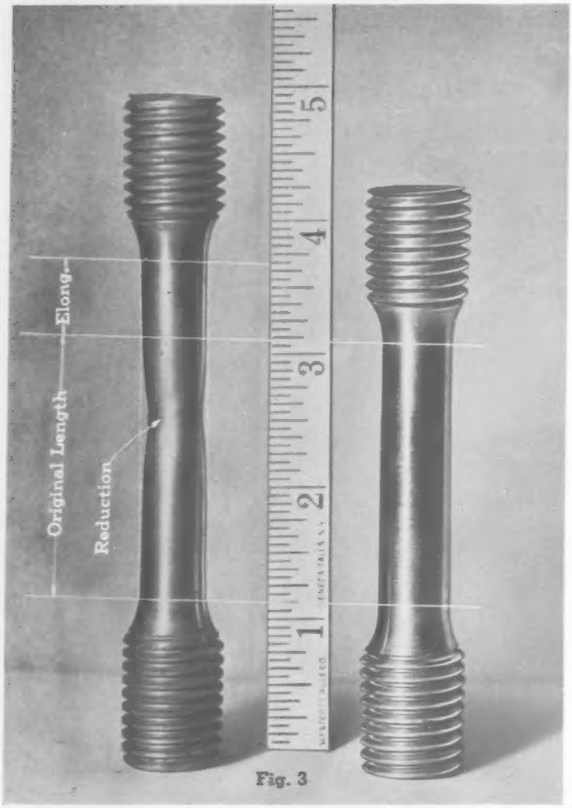


Fig. 3

highly polished rolls of proper contour insures flat products with highly finished surfaces.

With this new combination, the electrical requirements also were revolutionized, for greater amounts of power were necessitated. This development also emphasized the emergence of the control engineer as an important factor in dealing with the problem. The necessity of controlling simultaneously a multiplicity of mills or stands added greatly to the amount and complexity of control equipment required but presented no great difficulties.

Add to this such items as the accurate measurement of gauge at varying speeds; screw pressure measurement; speed variation from slow "thread speed" when entering the strip through the several strands to maximum operating speeds; control of mill operations from a multiplicity of points so that each of several operators may work in co-ordination; measurement and accurate control of tension and speed regulation of individual units in order to obtain maintenance of tension; coiling of the finished strip on the reel so as to maintain constant tension with varying speeds and coil diameters — and a general picture of the problem is presented.

This type of mill was successful; and originally, with delivery speeds of 300 to 400 feet per minute on average widths, about 100 tons in eight hours on lighter gauges was considered satisfactory production.

As is universally true, progress comes not only from methods but also from gradual improvements in devices, tools, and operating technique. The following obstacles in the tandem mill preventing further improvement in operation had to be dealt with:

1. Necessity for rapid and delicate adjustments of speeds and screw (roll) pressure
2. Requirement of delicate roll contour
3. Difficulty of co-ordinating changes in a series of stands
4. Difficulty in keeping proper tension between stands
5. Shutdown of entire mill due to interruption of one stand
6. High investment per unit production
7. Reduced speed of operation of all but the last stand (it is commercially advantageous to build all stands in duplicate)
8. Large power per unit reduction.

The steckel mill

Shortly after the tandem mill first came into general use, the problem was attacked from a somewhat different angle. The rolls previously used had been

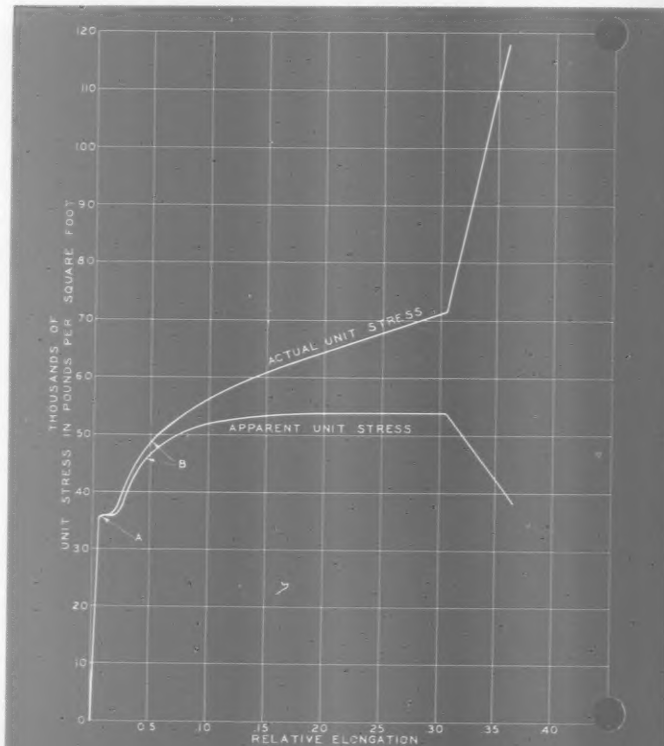


Fig. 4

of relatively large diameter, as shown by the dotted lines in Fig. 6A. Obviously the pressure of the roll contour against the strip was spread over a relatively large area.

The advantage of using small rolls became apparent. As shown in Fig. 6A, the area of contact is much less. For a given allowable total pressure, the reduced area of contact results in increased pressure in pounds per square inch. If, then, front and back tension be applied, increased reduction results with less required horsepower because of the decreased total surface friction. In consequence, the investment cost is lower than with other types. At the same time, improved surface and grain structure resulting from tension rolling are obtained.

Here a single four-high reversing mill is used, and the strip is passed back and forth through it to effect the desired reductions in a series of passes. Reels are disposed on either side, the sole motivating power being a motor connected to the forward reel to pull the strip through the mill. No power is applied to the main working rolls, which are relatively small in diameter, as stated above.

Originally, mechanical brakes were employed on the "trailing" or back reel to produce back tension. Because of operating difficulties and non-uniform results, these brakes were replaced with electrical machines, acting as drag generators, as soon as suitable control was developed for them. The main motor, by means of ratchet type gearing, is transferred to the opposite reel when the mill is reversed.

After extensive operating experience, the following limitations were found inherent in this arrangement:

1. The amount of tension was limited by the strength of the material on the delivery side; whereas the effect of tension was more pronounced in its effects on reduction on the entry side of the mill.
2. The main rolls were too weak to be driven by power.
3. Because of this weakness of the main rolls, the front tension deflected the main or working rolls horizontally, causing wrinkling in the strip and non-uniform rolling on the wider materials.
4. Because of these limitations, 10 to 15 passes were required to reduce low carbon steel from 0.065 in. to 0.0107 in. in strips 38 in. wide, and the maximum production was 15 tons or less in eight hours.

Consequently, in general, these mills are relegated to softer alloys or very thin strips of narrow widths and special requirements. Narrow strips have been rolled down to as thin as 0.001 in.

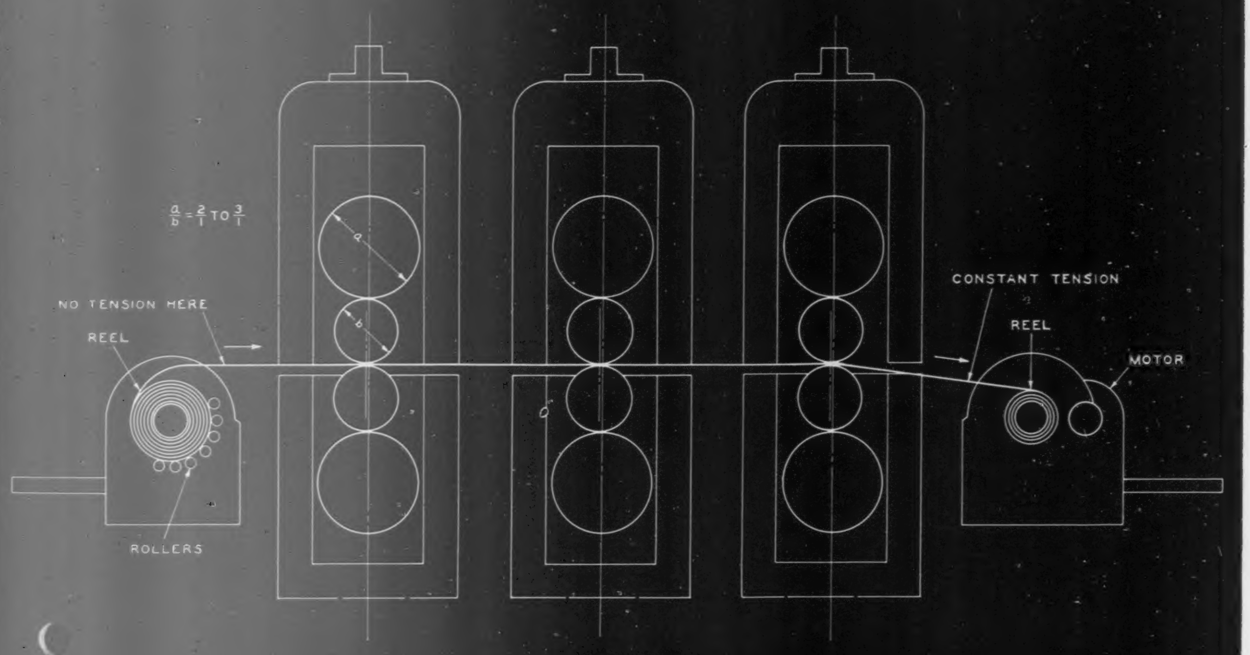


Fig. 5—Tandem Mill.

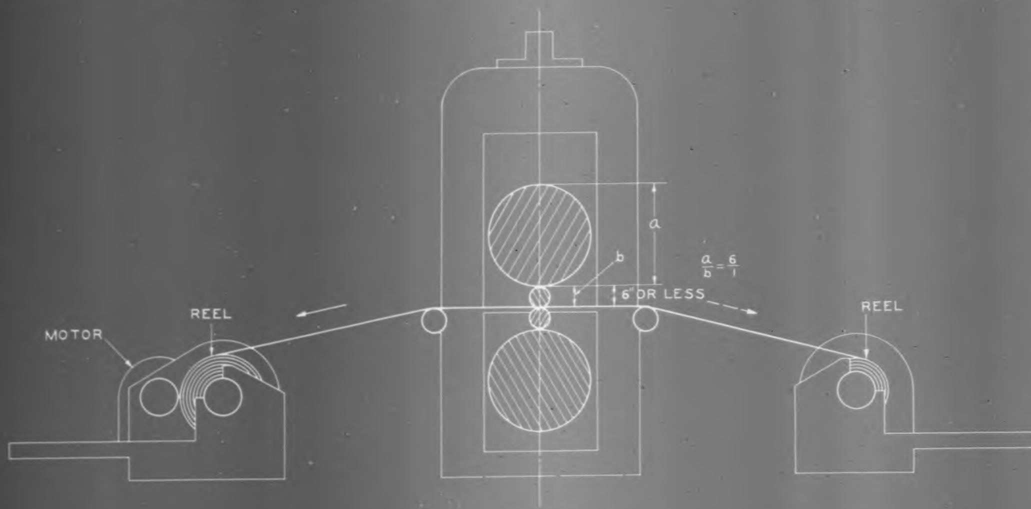


Fig. 6—Steckel Mill.

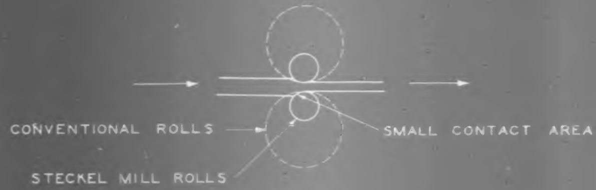


Fig. 6A

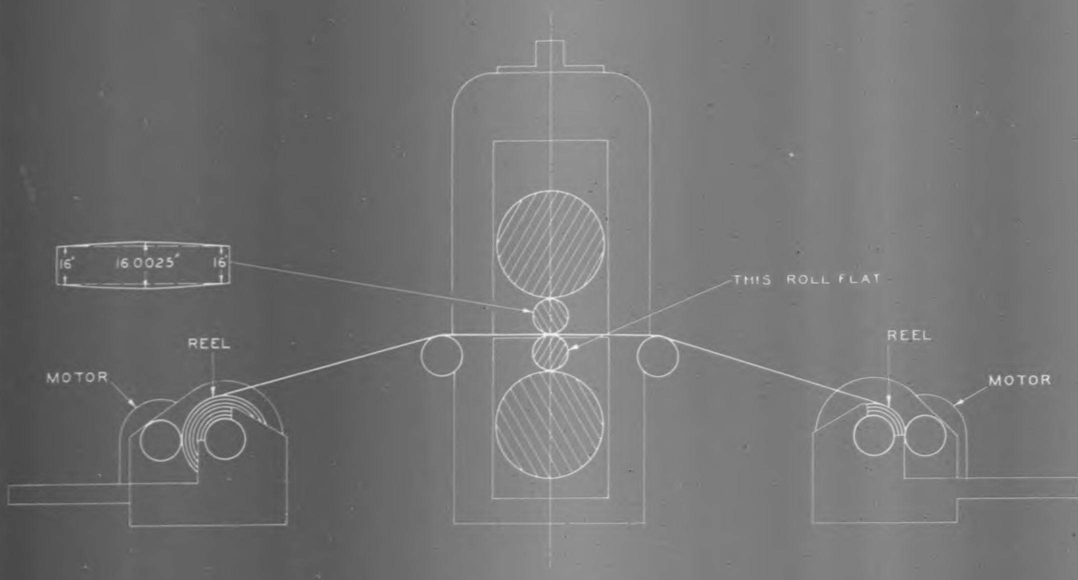


Fig. 7—Cold Reversing Mill.

The cold reversing mill

When the limitations of the Steckel mill became better understood, a more general study of the problem of cold rolling was undertaken by the industry as a whole. Soon another mill, known as the cold reversing mill (Fig. 7), was developed, which overcame the inherent limitations of the Steckel mill. In the cold reversing mill, the strip, as before, is passed alternately to the left and right through a single four-high mill from reels located on each side of the mill. However, the working rolls are of comparable diameter and strength to those of the tandem mill previously described and are driven by a d-c motor of suitable capacity.

Each reel has connected to it a d-c motor that acts alternately as a motor or generator, as the direction of the strip is reversed to give front and back tension. The speed of the strip is determined by the motor connected to the main rolls, and control has been developed to maintain constant front and back tension on the respective reels, at varying diameters of coils and varying strip speeds.

By having the main rolls power driven and of sufficient strength, a heavy roll pressure can be maintained without requiring tensions by the forward reel to be greater than the material being rolled will withstand. In addition, heavy back tension which is separately adjustable from the adjustments of the mill and forward reel can be maintained.

Obviously, since the material is thicker on the entry side before being reduced, it will withstand a heavier tension than the thinner strip on the delivery side. Referring again to Fig. 6A, as practically all of the surface contact between roll and strip occurs to the left of a vertical line through the center of the rolls, the heavier the back tension, the less friction on the contact surfaces between roll and strip. Forward tension tends to increase this friction.

Therefore, larger reductions, better grain structure, and smoother finish are obtained with a relatively large differential between back and front tension and with a smaller number of passes. The front tension is as small as it can be made and still pull the unevenness out of the strip as it is coiled. Actually, under these conditions, the heavy back tension adds to the swaging action of the main rolls.

With this mill, it is possible to cold-reduce low carbon hot finished sheet or strip from 0.065 in. to 0.0107 in. thick in three passes. With linear speeds of approximately 500 feet per minute on the first pass and approximately 800 feet per minute on the second and third passes, approximately 50 tons of 38 in. wide strip may be produced in eight hours. Fig. 8 shows an actual installation of a 42 in. two-stand reversing cold mill of the type illustrated in Fig. 7.

In summation

For large scale production, the tandem mill and the cold reversing mill have been made available. With mill speeds which were in effect about five years ago, the production of the cold reversing mill was about seven to eight times that of the old hot mill, and working conditions were infinitely better. The steel quality was such as to permit improved quality of products, as indicated above, but the mill investment cost had increased by a large ratio. The production ratio of the tandem mill over the old mills was perhaps twice that of the reversing mill.

It will be appreciated that accuracy of control is most important under all conditions and speeds for successful results. With the development of control to a finer degree, as well as improved mill construction, etc., in the succeeding years the operating speeds of such mills have been gradually raised. Also, it has become general practice to weld small coils together to form a large coil before cold reducing.

Perfection not yet attained

Tandem mills now operate at 1600 feet per minute with coils approaching 50 in. in diameter in the finished state, producing 200 to 300 tons of 38 in. wide tin plate (0.065 in. reduced to 0.010 in.) in eight hours, with productions under ideal conditions occasionally running as high as 500 tons. On heavier strip steel, in widths up to 78 in., production in tons is commensurately higher. On mills under construction, approximately 50 percent increase in speed over the above are provided for.

While the speed of the reversing cold mill has been raised, it has not increased proportionately to that of the tandem mill. The reasons involve problems relating to the individual types of mill which are beyond the scope of this discussion.

A word may be said, however, as to the field of application of the two types. On large orders for the same grade of steel at the same gauge and width, once the proper rolls are put into the mill, rolling may continue, coil after coil, until the roll surfaces are worn or defaced. For such a schedule, the tandem mill is well adapted. On the other hand, on orders involving relatively few coils of a given width, when an order of one width has been rolled, the extent in width of roll wear equals the width of the strip being rolled. Thus, uneven products may result from attempting to roll a wider sheet, necessitating frequent roll changes. The reversing mill, which has only a single set of rolls to change, is more adapted to this kind of schedule. In addition, its initial cost is much lower.

This increase in speed and production rates has brought with it, as in previous advances in the art of rolling, certain problems. For reasons as yet not fully beyond the theory stage, when a strip is put

through a mill at low speed and roll pressures and tensions and other necessary factors, such as lubrication, etc., are adjusted to produce the desired gauge delivered from the mill, if the adjustments are left fixed and the mill is raised to full speed, too thin a gauge will be produced.

Conversely, with conditions correct at top speed, when the mill is lowered in speed, the material being rolled will become thicker as speed is reduced, causing off-gauge or off-weight material. It is necessary that the strip be "threaded" at low speed and that the speed be reduced at the end of the strip. Furthermore, the more the top speeds of these mills are increased, the more off-weight material will be produced, which can become a costly item.

These problems must be solved by proper analysis and application of the right kind of control. One method of approaching the solution has been to decrease the time of acceleration and deceleration. However, since the rotating masses, including the mill rolls, absorb a relatively large stored energy in accelerating quickly, the power equipment may be exorbitantly increased in initial cost if the accelerating time becomes too short. Also, the control of the equipment must be more accurate and quicker in response. It is obvious that, under these circumstances, practical limits may easily be exceeded.

Thus new and involved problems face the control engineer. More than ever before, all elements of the mill equipment must be balanced and co-ordinated in order to obtain the results warranted by such large investments. It therefore follows that the efforts of the engineer, the operator, the mill builder, and the electrical manufacturer must necessarily be co-ordinated. It will require harmonious teamwork to insure real progress. And such progress will be reflected in ever greater public utilization of tin cans and American Beauties.

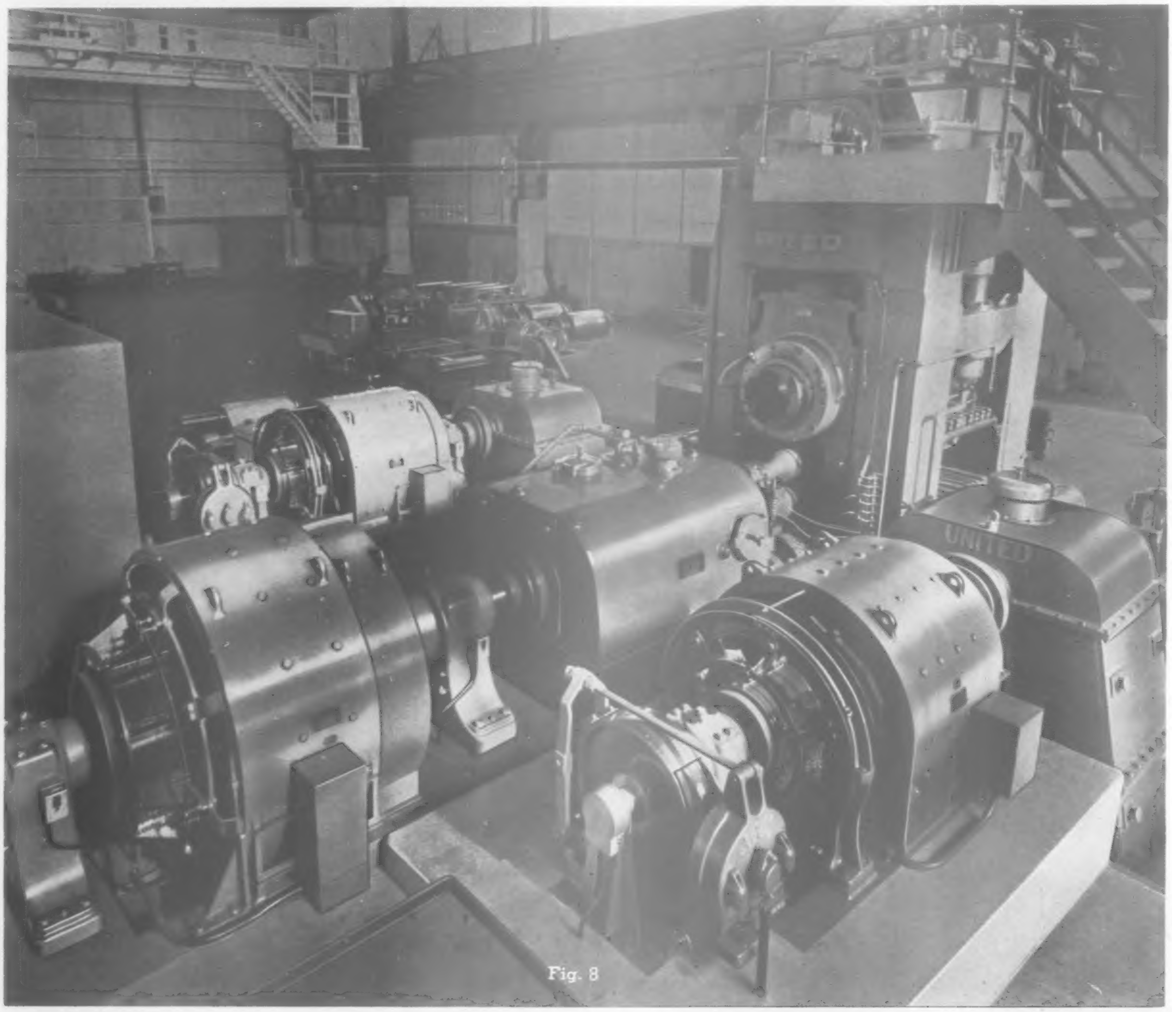


Fig. 8

SIXTY SECONDS' WORTH

W. M. Pickslay

SWITCHGEAR DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

Customers' clocks slow down as load goes up . . . and the problem of small power plants today is to give 60 seconds' worth of current every minute of the 24-hour day. Here are three low-cost ways to do it.

The increasingly general use of electric clocks and other timing devices has created a demand for close control of power plant frequency. In large plants this requirement usually presents no particular difficulty, as the load variations are generally small with respect to the plant generating capacities, and accurate frequency can be easily maintained by manual control. In the few cases where the load variations are heavy and frequent, requiring automatic regulation of frequency, the cost of the necessary regulating equipment is slight in comparison to the total cost of the plant.

In small plants, particularly municipal and private industrial power plants, the problem is quite different. Such plants may have widely varying loads, and a single load may be as high as 25 percent of the installed generating capacity. Maintaining accurate frequency under these circumstances requires constant attention on the part of the station operators. Conventional frequency regulation cannot be resorted to because of prohibitive cost of the equipment in percentage of the plant investment. It therefore becomes important to examine the possible ways of maintaining a reasonably accurate frequency in small power plants at commensurate cost.

A typical load day

As the first step in the consideration of this problem, reference is made to Figs. 1, 2, and 3, which show typical 24-hour records of small power plant load, frequency, and accumulated time error, respectively. The records have been purposely exaggerated, particularly in respect to load changes, to afford a clearer picture of what takes place.

Starting at 12 midnight, the load is light and tapers off slowly until the minimum load is reached at about 7 a. m. Each time the load drops off, there is a rise in the station frequency due to the drooping characteristics of the prime mover governors usually required for proper parallel operation; that is, the governors regulate for a lower frequency at full load than at no load. A certain time is required to restore the frequency to normal, as indicated by the record, whether automatic or manual control is employed. Consequently during the time when the frequency is above normal, as indicated by the shaded portions in Fig. 2, a clock connected to the station bus will gain time with respect to a standard clock. For example, as shown in Fig. 3, if the station clock were accurate at 12 midnight, it would be one minute fast at 7 a. m.

From 7 a. m. to about 10 a. m. the load curve rises sharply, with the load increases causing lowering of the station frequency. As before, since it takes time to correct the frequency errors, the station clock will lose time with each load increase and will be 50 seconds slow at 10 a. m. During the rest of the day the station clock can be expected to gain and lose time because of the decreased loads during the noon and late afternoon periods. As shown in Fig. 3, the net result is that the station clock is 20 seconds slow at the end of the 24-hour period.

These records are based on immediate correction of all frequency variations by either manual or automatic control. It is apparent, therefore, that under conditions where the frequency errors are not corrected immediately, the accumulated time error can attain — and does in many cases — as much as several minutes in a 24-hour period.

The first and obvious step toward maintaining an accurate frequency is the installation of a synchonous motor-driven clock energized from the station bus. This clock may then be compared at frequent intervals with radio standard time signals or one of the time services. When the station clock runs slow, it merely indicates to the station operator that the frequency is in need of correction and must be increased slightly until the lost time is made up, or vice versa.

Isochronous governor regulation

The first method of securing automatic control of the plant frequency is one which is not applicable in all cases. This consists of operating one of the installed generating units with no droop in the gov-

ernor characteristics; that is, the governor regulates for the same frequency at all loads. This method can result in quite accurate frequency control, but it requires an accurate modern governor of the isochronous type; that is, the governor must be of the type that does not depend in any way on the use of a drooping characteristic to secure stability in single or parallel operation of units.

It also requires that the unit so operated be the largest one installed, or one with sufficient capacity to take all the load variations, since the units whose governors are not so set will run at constant load. It is not possible to operate more than one unit of a group in parallel without a drooping characteristic in its governor.

The accuracy of control secured in this manner will, of course, be only as accurate as the governor. However, with this method a decided improvement can be expected, and the accumulated time error may be cut down from minutes to seconds. The necessity of comparing the station clock with a standard clock is, of course, still present, but this checking can be cut down to once or twice a day, at which times the speed setting of the governor with zero speed droop should be raised or lowered slightly according to the requirements.

An objection to this method of controlling frequency that is sometimes made is that the station load will not be divided between the generators in proportion to their ratings. To correct this condition, a simple current balance relay can be installed on each unit that would otherwise operate at a fixed load. Following an increase or decrease in station load absorbed wholly by the master unit whose governor has zero droop compensation, these current balance relays will, through auxiliary relays, operate on the remaining governors to balance each generator current with the master generator current in proportion to their ratings.

This is not, strictly speaking, load balancing. However, where voltage regulators with automatic cross-current compensation are used on each generator, the current balance will be, in effect, load balance. When voltage regulators are not used, which is becoming increasingly rare nowadays, the station operator, by exercising reasonable care to maintain equal power factors on the various generators, can provide fairly accurate load balancing.

It is suggested that the current balance relays be relatively insensitive, perhaps allowing a 20 percent unbalance in currents, so that no additional equipment will be necessary to prevent hunting. This will result in keeping the load control equipment as simple as possible and will decrease the frequency of operation of the load control mechanism. Consequently, the wear and resultant maintenance of the equipment and the governor synchronizing motors will be minimized.

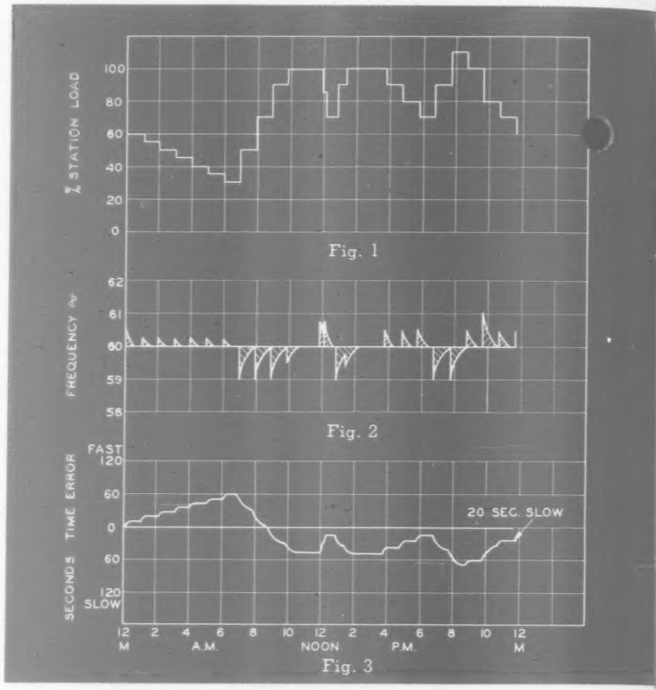


Fig. 1

Fig. 2

Fig. 3

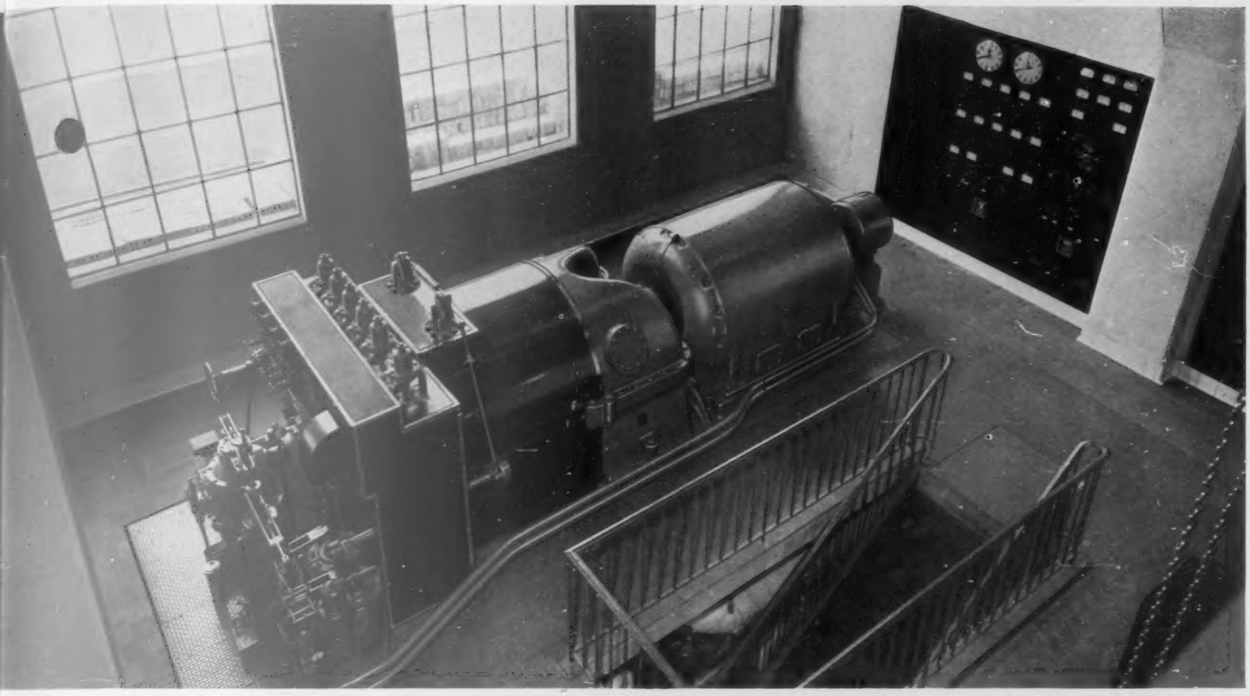
Regulation from adjacent system

While the foregoing is the logical frequency control to adopt, it is unfortunate that a great many governors, particularly the older ones, are not suitable for this procedure. In such cases, the plant may have access to a source of accurate frequency, such as an emergency lighting connection to a frequency regulated system. The obvious procedure would then be to keep the two systems in step even though it increased the cost of the connection somewhat. This could be simply done in a number of ways.

The most desirable would be an arrangement consisting of two synchronous motors, one energized from the plant frequency and the other energized from the reference frequency. A contact arrangement should be included to make contact whenever the station accumulated time error with respect to the reference time exceeded—20 seconds, for example. Closing of the contacts would, through suitable auxiliary relays, actuate one machine governor in a direction to correct the error. By allowing a comparatively large time error, the necessity for some means of anti-hunting may be obviated and the frequency of operation of the equipment reduced. Here again, if it were desired to keep the loads reasonably equalized on all units, it would be necessary to include load control apparatus such as described.

Impulse type frequency regulator

If a separate source of accurate frequency or a suitable governor is not available, an impulse type of frequency regulator is necessary. This type of regu-



The turbine floor of a small modern power plant (generating capacity 1000 kw), showing the two clocks — one with radio time and the other energized from the station bus — perfectly synchronized.

lator consists of a contact-making instrument that has been made sensitive to frequency in one of a number of ways, which are not mentioned here. Such an instrument becomes in effect the same as the conventional form of frequency regulator in its barest essentials.

On the occurrence of a frequency change, through the medium of suitable auxiliary relays the regulator immediately acts to correct for the instantaneous deviation by altering the setting of one governor. As this operates on the instantaneous frequency error and not on the accumulated time error, its operation will be correspondingly more frequent. Furthermore, anti-hunting circuits will be required, as well as load control equipment, if it is desired to maintain equal loads on the paralleled units, since it is impractical for the frequency regulator to control more than one unit at a time.

The accuracy of frequency control secured with this type of control will not be comparable to that secured with an accurate governor because both the impulse frequency regulator and the governor have to act to correct the frequency, which means a slower return of the frequency to normal. Furthermore, in the interest of reducing cost, the impulse regulator is likely to be less sensitive than the governor.

It can be expected, however, that such a regulator will keep the frequency accurate within perhaps 20 to 30 seconds accumulated time error in a 24-hour period after some experience with the adjustment of the regulator has been gained. It will still be necessary to compare the station clock with the radio time signals or other time service at occasional intervals. The accumulated time error can then be eliminated by subsequent operation at a slightly higher or lower frequency setting of the regulator. The daily increases and decreases in load can be expected to cancel out somewhat, although in general the station clock will lose time. Experience may show that the remaining time error can be eliminated by setting the regulator to maintain a frequency higher than normal, such as 60.1 cycles.

To sum up, three possibilities are open: first, when suitable governors are available, accurate frequency control is obtainable by proper governor settings; second, if a reference source of accurate frequency is available, accurate frequency is simply secured by maintaining a constant relationship between the regulated plant frequency and the reference frequency; third, an impulse type frequency regulator may be used, giving reasonably accurate regulation although not so good as the first two alternatives.

Where very accurate control is required, the conventional type of frequency control, requiring a master clock and considerable accessory equipment in addition to a highly sensitive frequency regulator, is necessary. However, any of the three proposed methods will give reasonably accurate frequency control at a cost that can be justified for small power plants.

CHECK YOUR OIL, SIR?

J. J. Onarheim

TRANSFORMER DIVISION • ALLIS-CHALMERS MANUFACTURING COMPANY

You can't drive your transformer into a service station . . . but that doesn't mean transformer oil shouldn't be checked periodically. If you're out to get the most from your transformers, read this article.

For more than forty-five years oil has been used almost exclusively as the principal insulating and cooling medium for transformers. Just as transformers have been the most dependable of all electrical machines, so has the transformer oil used in the past decade required a minimum of maintenance. This low maintenance requirement of transformer oil is due in part to the improved quality brought about by years of research and actual service experience. The means for securing long oil life and for preventing oil deterioration are now well known and are commonly employed in modern transformer construction.

Materials and design

When catalytic agents come in contact with oil, organic acids tend to form in combination with whatever moisture is present. These organic acids in turn cause the precipitation of soap type sludges, which reduce the dielectric strength of oil and other insulating materials. As the types of metals, varnishes, paints, etc., that act as catalyzers are known, the materials used in the construction of present-day transformers are selected from those having minimum catalyzing effects. Inert gas systems, which tend to lower the oxygen content of oil, and expansion tanks both further reduce the catalyzing effects of the materials used.

In a properly designed transformer, adequate electrical clearances are provided so that the oil will not be over-stressed at any point. If the oil is of good quality and is not contaminated, sludging by corona or electrical breakdown should not occur, and electrical fields should not cause gaseous decomposition.

AT LEFT: One of thirty-two 20,000 kva, single phase transformers at Los Angeles, Cal., with inert-gas protection.

Oxidation

Oxidation caused by oxygen from the air is responsible for most of the oil deterioration. The amount of oxidation increases with the temperature and surface area of the oil that is in contact with the air. At 25 C there is slight oxidation, but at temperatures higher than this the sludge may double for each 10 degree rise in oil temperature.

As much as 15 percent air by volume may be absorbed by transformer oil. This absorbed air is in close contact with the oil, so that, if the oxygen content is high, considerable sludge formation may occur. The asphaltic type sludge that is formed by this oxidation usually collects in the warmest parts of the transformer core and coils.

When oil is placed in a transformer, chemical changes begin to take place immediately. Organic acids, formed primarily because of the oxidizing effects of the oxygen in contact with the oil, may be present without any visible indication of sludge; but the acidity or neutralization number of the oil, which is a measure of this acid formation, can readily be determined by test.

The acidity test is one of a number of tests which, taken together, enable one familiar with transformer oil to tell the condition of the oil. The acidity is determined by the weight in milligrams of potassium hydroxide required to neutralize the acid in one gram of oil. This test is covered by a tentative standard of the American Society for Testing Materials designated as D-188-27-T and entitled "Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants."

Many surveys and reports in regard to the condition of insulating oil in transformers in service have been made. One of the most extensive was that issued by the Oil Insulating Subcommittee of the National Electric Light Association in 1932, which

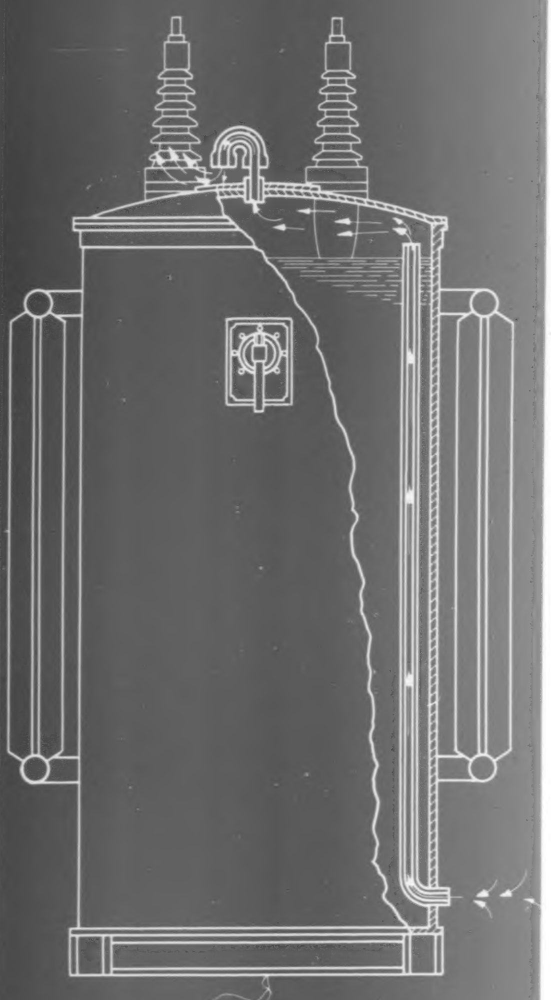


Fig. 1

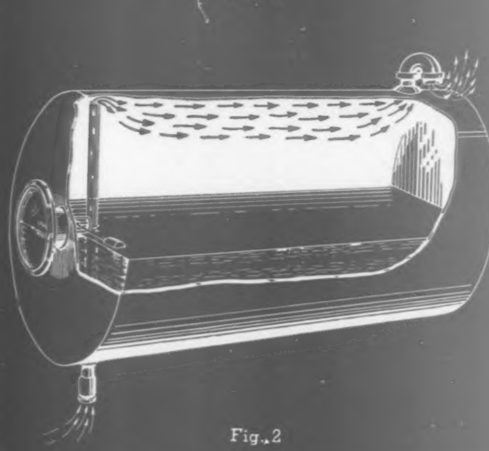


Fig. 2

covered five years' operating experience with large high voltage power transformers. This test report included dielectric strength and neutralization values for fifteen transformer oils used in transformers manufactured by seven different manufacturers.

It was found that the increase in neutralization number of the oil at the end of five years averaged 0.05 for transformers provided with inert gas protective systems, 0.11 for transformers with expansion tank arrangements, and 0.17 for transformers without either. When new, the oil in these transformers tested 0.03 or lower. These numbers, together with the other characteristics of the oil, provide a criterion for determining the suitability of the oil.

Room for expansion

Space is provided in all oil-filled transformers for the oil expansion resulting from increased loads. As was stated previously, the amount of sludge formation due to oxidation caused by oxygen in the air is dependent upon the surface area and temperature of the oil that is in contact with the oxygen. Therefore, by providing an expansion tank (see Fig. 2) attached to the main tank in which the rise and fall of the oil can take place, a much smaller surface area of oil results, and the oil which comes in contact with air is at a much lower temperature. The expansion tank also prevents moisture condensation on the inside of the transformer cover.

Comparisons between transformers not equipped with expansion tanks and expansion tank equipped units in like service have shown marked reductions in sludge formation in the expansion tank equipped units. By installing expansion tanks on all larger transformers, oil maintenance can be materially reduced.

Breathers

Small transformer cases are sometimes built without breather openings. These cases, however, must be perfectly air-tight, because if air enters through some defective joint, the moisture in the air may condense; and under some operating conditions the resulting oxidation can be so severe as to cause the cover to rust away completely in places. Moisture, loose rust scale, and other materials can then drop into the oil and introduce possible hazards. In order to eliminate this danger, it is desirable that transformers without breathers be made air-tight.

An alternate arrangement is to provide an opening to the atmosphere, called a "breather," to allow for normal expansion and contraction of the air above the oil due to varying loads. Several types of breathers have been developed. Some remove the moisture from the air as it is breathed in, and others provide a free circulation of warm air which prevents condensation of moisture.

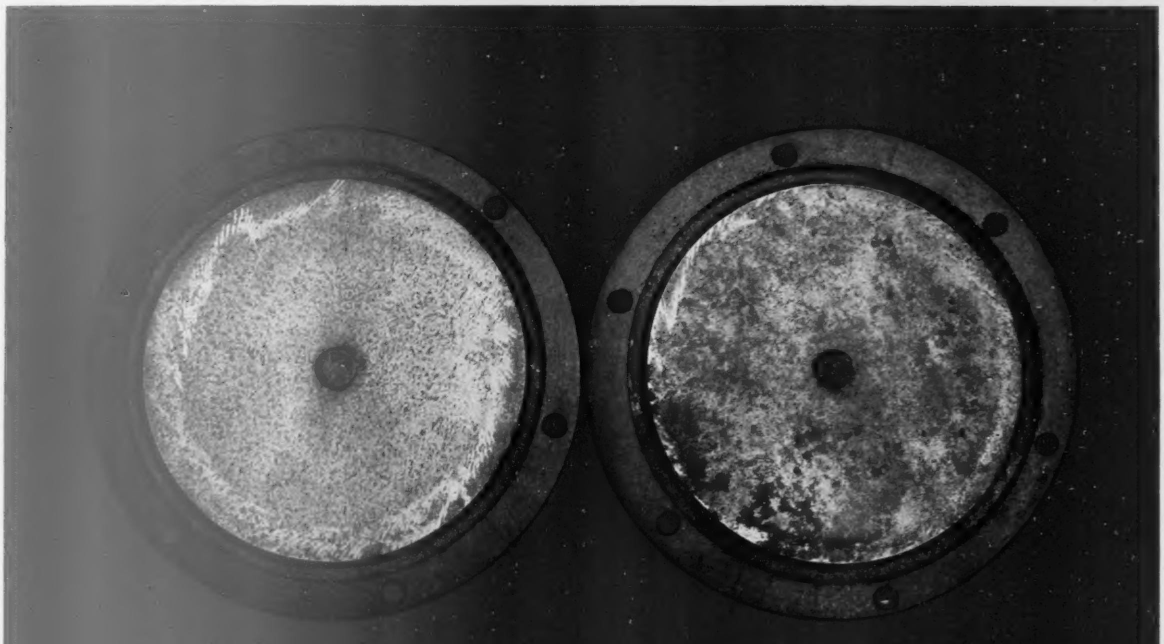


Fig. 3 — With Uni-directional Breather

Fig. 4 — With Ordinary Breather

A calcium chloride type of breather has been employed on some transformers to remove moisture from the air before it enters the transformer. This type of breather has been generally abandoned, because it requires frequent servicing in order that the calcium chloride does not become saturated with moisture and permit moisture to enter the transformer case. Other types of mechanical breathers that require maintenance have been developed, but the servicing which most types require is generally considered objectionable.

A simple breather which serves the purpose without requiring chemicals or maintenance is shown in Figs. 1 and 2. This so-called "uni-directional" breather consists of a pipe open to the air near the bottom of the transformer tank and extending upward through the oil and projecting above the oil surface. On the opposite side of the tank is an ordinary breather outlet.

The air enters the lower or intake end of the breather, is warmed by the hot oil in the transformer, rises in the pipe, and flows across the air space and out of the top outlet breather. This movement of warm air over the surfaces effectively reduces condensation and keeps the tank walls and cover dry and free from rust. The effectiveness of this breather is demonstrated by the comparative condition of the two covers shown in Figs. 3 and 4. Screening is pro-

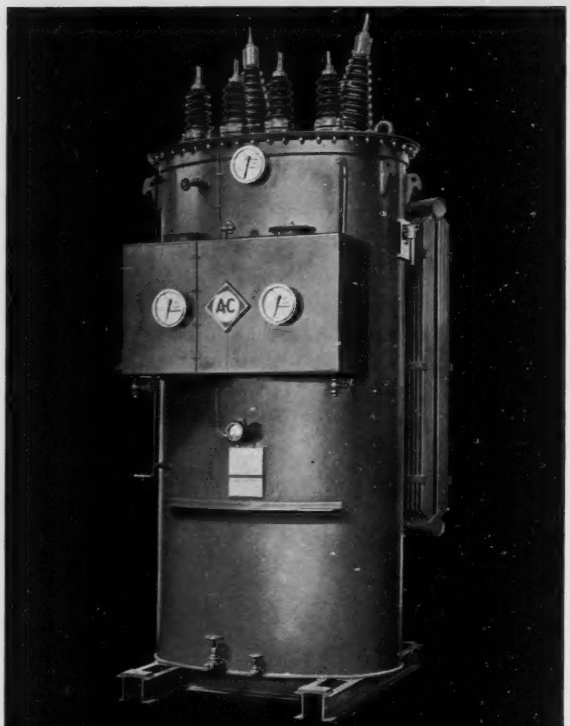


Fig. 5

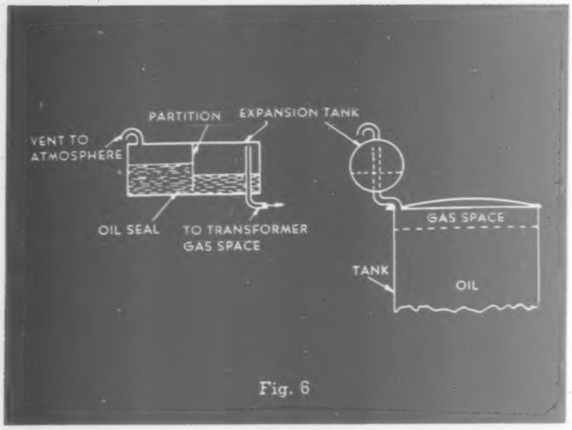


Fig. 6

vided in the breather openings to prevent the entrance of dust particles, lint, insects, and other foreign matter.

While the oxidation or sludging of oil in a transformer that is equipped with an expansion tank may not be excessive, the development of the inert gas filled transformer* reduces the oxidation to a negligible amount. One form of inert gas protection, shown in Fig. 5, has the expansion tank on the side of the case. In Fig. 6, the expansion tank is mounted on the cover in the conventional location above the oil level.

Oil rejuvenation

In addition to filter press and centrifuge apparatus, chemical oil treating systems are sometimes used to treat transformer oil when the oil has deteriorated. Some of these systems are very similar to the equipment used in the original refining processes. These treating systems are necessary mainly on transformers that have no expansion tank or inert gas protection.

Filtering by the filter press method or the centrifuge method removes moisture, insoluble sludge, and other foreign particles but does not remove soluble acids. These soluble acids are largely organic naphthenic acids and can be removed only by a very extensive and costly process used by petroleum refineries.

Briefly summarized, with this method these acids are removed by sulphuric acid, which makes them insoluble and therefore easily removed by precipitation. The oil is then washed with water and caustic soda and then given a final and complete washing with water. The oil is then passed through activated clays or fullers earth to remove any other impurities in the oil. When the oil is finally passed through a filter press, most of the desirable qualities of the oil are restored.

* See article "Inert Gas Protection for Transformers" by L. H. Hill, Allis-Chalmers ELECTRICAL REVIEW, March, 1937.

Sometimes oil is simply passed through activated clay, but this procedure of partial refining is not recommended for the treatment of transformer oils. As most of these clays are alkaline in nature in order to remove soluble naphthenic acids, they will react with the acids to form soluble naphthenic acid soaps, which will remain in the oil and, increase the tendency of the oil to emulsify with water. Even a slight trace of these soaps will increase the emulsification number of an oil by several hundred percent. In fact, they are widely used in industry today to form so-called "perfect emulsions," namely, soluble-cutting oils.

Therefore, if moisture enters the transformer, there is possible danger from the point of view of moisture emulsifying with the oil and reducing the dielectric strength at some vital point. When water is present in the oil and the steam emulsification number is low, as it is when the oil is in good condition, the water will separate out of the oil and settle at the bottom of the transformer tank or expansion tank where it will not have a damaging effect on transformer insulation.

The costs of reclaiming oil vary from about five cents a gallon to 15 cents a gallon, depending upon the equipment that is used and the amount of oil reclaimed. It is often more economical to purchase new oil.

Safeguards

The investment in a transformer should not be jeopardized by operating with oil that has deteriorated to the danger point. The following general observations can be used as a guide in determining whether the oil is in operating condition:

1. High acid content as measured by the neutralization number test does not necessarily mean that the acid in the oil will injure insulation or metals in the transformer.

2. High acid content of the order of 0.5 to 1.0, with no evidence of sludge formation, is probably not serious; but values as high as these indicate that the oil should be examined for other evidences of deterioration.

3. Evidence of considerable sludge formation with a low acid content may not be serious unless the amount of sludge is sufficient to clog cooling ducts and cause hot spots.

4. The combination of high acid content with evidence of considerable sludge formation should not be tolerated.

5. When the dielectric strength of transformer oil decreases to 20 kv or less, the oil should be reconditioned or replaced.

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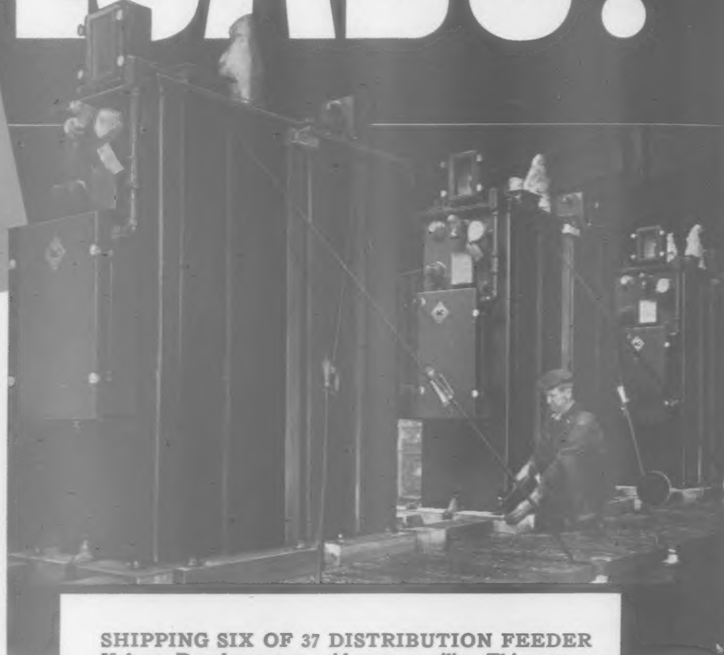

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A	18	270	90	180	1,350
B	1200	30,000	10,000	20,000	150,000
C	1800	31,500	10,500	21,000	160,000

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